12e Congrès des Doctorant·e·s de L'Observatoire de Lyon

Abstract booklet

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Amphithéâtre ISTIL Polytech Lyon

Program

9:00 – 09 :45	**Opening speech**
09:45 – 10:15	**Poster presentations**
10:15 – 10:45	**Break + Poster Session**
10:45 – 11:45	**Session A: Planetology**
10:45 – 11:05	Degree-one convection pattern during the lunar magma ocean solidification *Line Colin*
11:05 – 11:25	Investigation of the regolith properties at the four emirates lunar mission candidate landing sites *Marine Joulaud*
11:25 – 11:45	Valley Network Controls on Martian Aeolian Processes - Nirgal Vallis Case Study (Mars) *Inès Torres*
11:45 – 12:25	**Session B: Astrophysics**
11:45 – 12:05	The evolution of dust during the protostar formation *Antonin Borderies*
12:05 – 12:25	Etude d'une séquence de condensation expérimentale en milieu riche en carbone : modélisation thermo-cinétique et implications pour la condensation autour des étoiles AGB *Marwane Mokhtari*
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14:00 – 14:20	Use and development of innovative signal processing algorithms dedicated to improving detection and characterization capabilities of circumstellar environments by direct imaging *Thi My Hanh Tran*

14:20 – 14:40	Deep Learning for addressing the issue of parametrization in inverse problems *Théo Santos*
14:40 – 15:00	Urban Dark Fiber Distributed Acoustic Sensing for Bridge Monitoring *Julie Rodet*
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15:00 – 15:20	À la table des Incas : le menu des enfants sacrifiés dévoilé par la géochimie isotopique *Eve Poulallion*
15:20 – 15:40	Etude des pratiques de l'allaitement et du sevrage chez les grands singes via l'analyse isotopique de leurs dents *Danaé Guiserix*
15:40 – 16:10	**Break + Poster session**
16:10 – 17:10	**Session F: Palaeontology**
16:10 – 16:30	Letting fossil birds talk about deep time seasonal migrations: an isotopic and histological approach *Anaïs Duhamel*
16:30 – 16:50	Voay robustus, histoire d'un subfossile controversé: implications de l'anatomie endocrânienne et des datations radiocarbone à la biogéographie des crocodiles de Madagascar *Gwendal Perrichon*
16:50 – 17:10	The oldest African echinoderms (Morocco): morphology and implications for the diversification of blastozoans in the early Cambrian *Christophe Dupichaud*
17:10 – 18:00	**Award ceremony & Closing speech**

Posters

200 Ma of magmatism along the northern border of the West African Craton during Pan-African convergence
Alex Bisch

Carbonaceous organic material evolution inside icy moons
Camille Delarue

On the radial profile of filaments formed in a turbulent context
Pierre Dumond

Quantification du signal de déformation de surface dans la région du karst de Fontaine de Vaucluse (France)
Farès Mokhtari

Thermal evolution of the lunar magma ocean and comparison with Mars
Line Colin

Tracking feedbacks between fluid-rock interactions and brittle-ductile deformation processes in mantle wedge jadeitites
Clothilde Minnaert

Using lipid biomarkers to reconstruct past variations in methane cycle in North Cameroon: the NGaoundaba peat record
Valentine Schaaff

200 Ma of magmatism along the northern border of the West African Craton during Pan-African convergence

Alex Bisch[1]

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Convergence zones are marked by a variety of settings that may follow each other in modern-day tectonics, including compressive phases such as subduction, obduction, collision but also extensive ones such as back-arc opening or stress-relaxation during orogenesis. Hence, the protracted evolution leading to a super-continent block amalgamation may be difficult to decipher and so may be the forcings on external enveloppes such as volcanism or erosion caused by the different phases.

This question arises critically at the time of the Pan-African Orogenesis (1-0.5 Ga) assembling Gondwana, a time of supposedly dramatic and diachronical changes for external envelopes: glaciations of debated scales, deposition of various Banded Iron Formations, first (Ediacarian) fauna, replacement by Cambrian faunas. Our goal is to explore in detail the geodynamical succession leading to the amalgamation of blocks along the northern margin of the West African Craton (WAC), outcropping in the Central Anti-Atlas region, Morocco. This region is characterized by the occurrence of extended convergence-related magmatism, ophiolite emplacement and basins fillings (including BIF) during Cryogenian and Ediacaran periods.

Data obtained from compilation of cartographic work, whole-rock geochemistry and datation reveals a polyphased but still poorly constrained evolution presented here. Discussion starts on how metamorphic petrology, basin stratigraphy and trace element analysis coupled with datation in detrital zircons would help in order to better understand the evolution of the geodynamic, magmatic and drainage systems.

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Carbonaceous organic material evolution inside icy moons

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New models on the interior structure of the icy moons allow a large fraction (20-50%) of carbonaceous organic matter to be incorporated inside the silicate core. The incorporation of this material has been proposed in response to the bad match of values proposed by the previous models for the mass, moment of inertia, and density measured by the space mission. However, the impact of the temperature and pressure conditions inside the core of these moons have not been taken into account on COM. Carbonaceous organic matter undergoes important transformations both in terms of composition and structure when subjected to an increase in temperature and pressure. These transformations are characterized by the loss of heteroatoms (O, H, N, S) which lead to a huge variation of density going from 1200kg/m3 at 25 °C up to 2300kg/m3 at 1000 °C. In this work, we proposed to look at the evolution through temperature and pressure to create an equation of state describing the density transformation of COM. We studied separately the effect of temperature and pressure using Raman micro-spectroscopy and diamond anvil cell on different types of COM. The equation of state created was then applied to Titan with interesting results on both the amount of COM needed and its behavior inside the core. This work is of major interest in the context of the future JUICE and EUROPA CLIPPER missions which will study the icy moons giving better value for mass moment of inertia and density about the characteristics of the icy moons' COM structure and composition.

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On the radial profile of filaments formed in a turbulent context

Pierre Dumond[1], Gilles Chabrier

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Recent observations have exhibited that stars form preferentially along dense filaments (see e.g. André et al. 2019). A good comprehension of these structures is thus crucial to better constrain the star formation models. However, most of the observed characteristics of these filaments are still poorly understood. In particular, their radial profile is the subject of much debate because it appears much less steep that the one predicted by Ostriker (1964). Several models have been developed (Fiege & Pudritz, 2000; Fischera & Martin, 2012) to explain this profile highlighting the key role of magnetic field and external pressure. However, these studies consider that the structures are in equilibrium, a hypothesis that can be challenged: filaments are now often considered to be out of equilibrium because of an active accretion flow. Furthermore, the role of turbulence is not considered in these models.

Here, we propose that the radial profile of the filaments might directly arise from their turbulent origin. We compute the probability distribution of the shape of a 3D ellipsoid formed by lognormal density turbulent fluctuations and show that the average radial profile of the ellipsoid is very close to r^{-2} as widely observed. As the filaments seem to maintained in a quasi dynamical equilibrium by ongoing turbulent accretion flows, this profile should remain during the evolution. We also show that the most probable aspect ratio of structures formed in that turbulent context is about 4, of the same order as the values commonly observed in the interstellar medium. These first results suggest that a closer look to the turbulent origin of the filaments could help us to better understand their structure.

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Quantification du signal de déformation de surface dans la région du karst de Fontaine de Vaucluse (France).

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Cette étude est une analyse des séries temporelles InSAR calculées par la méthode NSBAS à partir des images Sentinel-1 sur deux tracks pour avancer dans la compréhension de la dynamique du système karstique du Vaucluse dans le sud-est de la France. L'approche est de tester plusieurs méthodes pour extraire le signal de faible amplitude associée à la déformation du sol, renseignant sur l'évolution du karst en profondeur. Des méthodes « type aveugle » ont été employées (PCA et ICA) ainsi qu'une approche « paramétrique », c'est à dire s'appuyant sur la série temporelle d'un autre paramètre, ici le débit en eau. L'Analyse en Composantes Principales (PCA) et l'Analyse en Composantes Indépendantes (ICA) ont permis d'identifier plusieurs types de bruit, notamment un signal atmosphérique, avec des tendances saisonnières annuelles. L'approche paramétrique a permis d'établir une relation entre la phase et les données de débit en eau. Des distributions spatiales spécifiques de la phase ont été identifiées. Grâce à l'utilisation de deux tracks, des mouvements verticaux et horizontaux dont l'amplitude pouvant varier jusqu'à ±2,5 cm ont été mis en évidentce. Ces signaux de déformation particulièrement importants quand le débit est maximal, sont ainsi temoin de l'évolution spatio-temporelle des phénomènes géologiques en profondeur et des dynamiques hydrologiques. La comparaison des deux méthodes indique que les méthodes non paramétriques, malgré leur sensibilité au bruit, fournissent une caractérisation robuste des signaux périodiques et des variations atmosphériques. La méthode paramétrique, en revanche,offre une meilleure localisation des zones de déformation et une plus grande précision dans l'identification des types et des directions de déplacements. Plusieurs directions pour des études futures sont proposées, y compris la modélisation des champs de déformation identifiés, l'intégration de paramètres environnementaux supplémentaires tels que la précipitation et la température, et le recalibrage des modèles atmosphériques pour minimiser les influences du bruit.

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Thermal evolution of the lunar magma ocean and comparison with Mars

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The energy of the Moon forming impact was large enough to generate an initially hot Moon, with a global magma ocean. During the solidification of this lunar magma ocean (LMO), an anorthosite crust formed by flotation of light anorthite crystals. Lunar anorthosites compose most of the Highlands and show crystallization ages spanning over 200 Myr. Existing models predicting the solidification timescale for the LMO are based on one specific phase diagram associated to a given compositional model for the Moon. However, the LMO solidification timescale largely depends on the lunar bulk composition and on the appearance of anorthite in the crystallization sequence.

Here, we propose a physically robust 1D model for the evolution of the Moon in its magma ocean stage ocean based on an anorthite-olivine eutectic phase diagram which allows to parametrize the initial composition and the start of anorthite crystallization in a simple way. Our model is based on the energy conservation equation for the LMO and the time-dependent thermal diffusion equation in the crystallizing cumulate and crust layers. These equations are solved to follow the evolution of the crust and cumulates thickness and temperature over time, and to compute the final crystallization time.

We explore the impact of an initially hydrated composition, which reduces the stability of plagioclase and results in a thinner crust and a shorter crystallization time. Depending on the initial composition, the eutectic position and the crust thermal conductivity, the solidification timescale for the lunar magma ocean is of 70 to 250 Myr.

We also explore the possible application of such a scenario to Mars. Using an initially wet composition and accounting for the density crossover between olivine and peridotite melts at ~7 GPa, an anorthosite flotation crust cannot exceed 30 km in thickness on Mars and would form in less than ~50 Myr.

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Tracking feedbacks between fluid-rock interactions and brittle-ductile deformation processes in mantle wedge jadeitites

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Deformation processes in the mantle wedge near the subduction interface are still poorly understood, especially as this region is commonly considered aseismic even though more and more seismic events are reported. Although geophysical evidence points out the role of fluid injection from the slab into the mantle wedge for triggering brittle deformation, precise mechanisms and fluid origin remain unclear. Jadeitites, commonly found in serpentinite mélanges, are directly related to these slab-derived fluids and are thus particularly useful for getting insights into fluid-rock-deformation interactions above the subduction interface. This study investigates the mineralogical and geochemical evolution of jadeitites from three different localities: Sierra del Convento (Cuba), Kachin state (Myanmar), and Borus Belt (Siberia). Microprobe data show that all samples display a complex mineralogical evolution with several generations of clinopyroxenes eventually associated with other mineral phases (amphiboles, micas etc.). Moreover, all the studied samples display brittle (brecciation, cataclasis) and ductile deformation features coeval with high pressure metamorphism. Trace element and isotopic data (B, Sr) indicate slight variations among breccia clasts and inter-clast matrix, thus revealing a complex and protracted evolution of fluid composition during brittle deformation. Some of the comminuted domains can be interpreted as foliated cataclasites, a structure commonly related to fault slip at seismic to sub-seismic rates. These findings disclose complex and intricate relationships between influx of a metasomatizing fluid and brittle-ductile switches, shedding light on fluid-rock and mechanical processes along the base of the mantle wedge.

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Using lipid biomarkers to reconstruct past variations in methane cycle in North Cameroon: the NGaoundaba peat record

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Methane (CH4) is an important greenhouse gas whose atmospheric concentration has increased by over 150% since 1750. Methane emissions can be of anthropogenic (fossil fuel, livestock, ...) or natural (freshwater wetlands, ...) origins with freshwater wetlands accounting for more than a quarter of total present-day CH4 emissions (IPCC, 2021). Complex biogeochemical feedbacks may affect CH4 release from wetlands. These feedbacks, such as influence of temperature, change in precipitation regime or in nutrient availability (Dean et al., 2018), still need to be more constrained. The use of lipid biomarkers proposed as potential tracers of methanogenesis or methanotrophy is a great opportunity to attempt to assess these feedbacks on a longer timescale (Naaf et al., 2019 and references therein).

In this study, we investigate the sedimentary record of a 10-ka peat deposit from the NGaoundaba peatland (Northeastern Cameroon). Using several microbial biomarkers [Isoprenoid glycerol-dialkyl-glycerol-tetraethers (isoGDGTs) and hopanoids] in parallel to temperature and precipitation reconstructions based on brGDGT and δDn-alkane, respectively, we propose an evaluation of past methanogenic and methanotrophic activities at a centennial timescale over the Holocene. Considering GDGT-0 as a tracer for methanogenesis in peatlands, we compare the absolute values and the relative abundances of GDGT-0 and Crenarchaeol. While the relative abundance of GDGT-0 and the ratio of GDGT-0/Cren decrease during the most humid period from around 7.9 to 5.8 ka cal BP, the absolute abundance

of GDGT-0 increases simultaneously, suggesting a complex evolution of the structure of the microbial community. The data suggest that the methanogenic activity and the microbial activity in general increased during this period, but that the relative proportion of methanogenic archaea in the microbial community decreased at the same time. The δ13C values of the C27 hopane are in agreement with the study of Inglis et al. 2019 that shows a contribution of methanotrophs as producers.

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Session A

PLANETOLOGY

Degree-one convection pattern during the lunar magma ocean solidification
Line Colin

Investigation of the regolith properties at the four emirates lunar mission candidate landing sites
Marine Joulaud

Valley Network Controls on Martian Aeolian Processes - Nirgal Vallis Case Study (Mars)
Inès Torres

Degree-one convection pattern during the lunar magma ocean solidification

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Although the classical scenario for the solidification of the lunar magma ocean elegantly explains the formation of an anorthosite crust by flotation of anorthite minerals, it does not explain the observed degree-one variation in crustal thickness of the Moon. The lunar crust is indeed significantly thinner on the near side (~20-30 km) than on the far side (~50-60km).

One suggestion is that a degree-one convection settles in the solid cumulates before the end of the solidification of the lunar magma ocean. Because, the phase change boundary between the cumulates and the ocean can allow matter to flow-through by melting and freezing, solid convection may indeed be facilitated and a degree-one pattern of convection could be favoured (Morison et al, 2019).

Here we construct a model of solidification of the lunar magma ocean based on a simple anorthite-olivine phase diagram. In a first stage, lasting hundreds of years, cumulates form at the base of the ocean. In a second stage, simultaneous crystallisation of anorthite and cumulates leads to the formation of a flotation lid which significantly slows down the cooling of the magma ocean. The total crystallisation timescale is of the order of 100 million years.

Using a linear stability analysis on the convection equations accounting for material exchange at the solid-liquid interface, we show that convection has time to set up in both the solid cumulates and possibly in the anorthosite crust before the end of the second stage of crystallisation.

We also show that a degree-one convection pattern is favoured in the solid cumulates, which can explain the observed nearside-farside difference in crust thickness.

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Investigation of the regolith properties at the four emirates lunar mission candidate landing sites

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Because of a lack of atmosphere, the Moon's surface undergoes different processes of space weathering which shape the non-cohesive layer above the bedrock: the regolith. In this study, two morphological traits of the lunar surface are analysed, the regolith thickness and the boulders density, at the four candidate landing sites of the Emirates Lunar Mission (ELM). Using high-resolution LRO NAC imagery and associated DEMs, we investigate the four candidate landing sites of the ELM: the floor-fractured crater Atlas (3.8 Gyr), and three maria, Sinus Iridum (3.4 Gyr), Oceanus Procellarum (1.9 Gyr), Lacus Somniorum (3.7 Gyr). We mapped 3,413 small craters (<350m) presenting a specific morphology: central mound, flat-bottomed or concentric. The thickness is calculated using the small crater morphology method. Boulders are manually mapped and overlaid on the LRO Diviner rock abundance and mini-RF CPR global maps. The Depth-Age hypothesis is not verified for the regolith thickness: Atlas has the thinnest regolith (1.7m in average), Procellarum and Somniorum have the same regolith thickness (2.1m), the regolith in Iridum is the thickest (3.5m). Regolith thickness and boulders density are not directly linked but rather have a complex relationship. When comparing the manual boulder mapping with the LRO Diviner rock abundance, results correlate in terms of values and overlapping. Atlas presents multiple specificities: a peculiar smooth texture from orbit, with a majority of small craters (<10m) and boulder fields far from craters, on topographic highs. Such specificities highlight complex surface processes, with a possible uplift bedrock at the centre of the crater.

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Valley Network Controls on Martian Aeolian Processes - Nirgal Vallis Case Study (Mars)

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Nirgal Vallis is one of the longest river valleys on Mars, stretching 700 kilometres across the Southern Highlands. Its cross section is a distinctive U-shape with a flat bottom and steep sides features. On early Mars, estimations show that the river drained up to 4800 cubic metres of water per second. Nirgal Vallis is the visible remains of this ancient river.

The flat floor of Nirgal Vallis is largely covered by transverse aeolian ridges (TARs), which indicate the prevailing wind direction along the valley's path. Our study focuses on how the valley shape dictates the aeolian features currently visible from the orbit, in order to characterize the sediment transport fluxes, and its interactions with ancient Mars rivers.

Our method consists, first, in identifying the TARs along the valley with the “Novelty or Anomaly Hunter – HiRISE” (NOAH-H) deep learning terrain classification algorithm, that classifies images from the HiRISE instrument with a resolution up to 0.5m. Our case study is the first to use NOAH-H in the Nirgal Vallis region – the algorithm was previously trained on Oxia Planum and Mawrth Vallis. We then use python scripts to extract the bedform edges from the classified images and finally derive the bedform orientations inside the valley, and outside its walls, to compare them.

Our results indicate that wind directions inside the valley are dictated by its shape. Therefore, material transported by the wind inside the valley will be trapped, converting the valley in a sediment sink that interacted with rivers on Noachian Mars.

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Session B

ASTROPHYSICS

The evolution of dust during the protostar formation
Antonin Borderies

Etude d'une séquence de condensation expérimentale en milieu riche en carbone : modélisation thermo-cinétique et implications pour la condensation autour des étoiles AGB
Marwane Mokhtari

The evolution of dust during the protostar formation

Antonin Borderies[1]

1 : Centre de Recherche Astrophysique de Lyon

Star formation is a key element to understand the life cycle of the interstellar medium (birth and death of stars, and their impact on the interstellar medium), so it is crucial to properly understand this phenomenon. Dust grains in particular, have a great impact on the birth of the protostar. Even though dust only accounts for only 1% of the total mass budget of the parent gas cloud forming the star, it plays a huge role in several mechanisms regulating the gravitational collapse. This talk will therefore present the results of my master's internship on the evolution of dust during the protostar formation.

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Etude d'une séquence de condensation expérimentale en milieu riche en carbone : modélisation thermo-cinétique et implications pour la condensation autour des étoiles AGB

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Les grains présolaires sont des cristaux micrométriques caractérisés par des signatures isotopiques qui excèdent largement les anomalies isotopiques observées dans les différents corps du système solaire. Pour cause, ces grains n'ont pas été formés lors de la condensation de la nébuleuse solaire, mais correspondent à des restes de la matière présente avant la formation du système solaire et qui n'ont pas été homogénéisés lors de la formation de ce dernier. Un certain nombre de ces grains sont des carbures (SiC, TiC) et ont été identifiés comme s'étant formés autour d'étoiles géantes de type AGB, par la condensation d'un gaz plus riche en carbone que la nébuleuse solaire.

Pour mieux comprendre la condensation dans ces conditions, une séquence de condensation expérimentale a été réalisée dans une torche à plasma gros volume à l'école des Mines, sur le site de Sophia-Antipolis. Un gaz de composition chondritique a été obtenu en injectant 600 grammes de poudre de chondrite ordinaire dans un plasma d'Ar et de H2. Le plasma est formé par trois électrodes en graphite dont l'érosion enrichit le gaz en carbone. Le gaz s'écoule dans l'enceinte de la torche où il se refroidit le long d'un gradient de température et peut condenser sur les parois ainsi que sur une canne en graphite. Les compositions minéralogique et chimique des condensats ont été analysées par la suite. Des modélisations thermodynamiques et cinétiques ont été réalisées pour interpréter la séquence de condensation et l'évolution des compositions chimiques observées. Des calculs similaires ont été réalisés pour modéliser la condensation autour des étoiles AGB riches en carbone. Dans de tels environnements, les interactions entre la lumière provenant de l'étoile et la matière condensée ne sont pas négligeables et nous avons calculé la séquence de condensation attendue compte tenu de ce phénomène.

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Session C

MODELISATION & GEOPHYSICS

Use and development of innovative signal processing algorithms dedicated to improving detection and characterization capabilities of circumstellar environments by direct imaging
Thi My Hanh Tran

Deep Learning for addressing the issue of parametrization in inverse problems
Théo Santos

Urban Dark Fiber Distributed Acoustic Sensing for Bridge Monitoring
Julie Rodet

Use and development of innovative signal processing algorithms dedicated to improving detection and characterization capabilities of circumstellar environments by direct imaging

Thi My Hanh Tran[1],

1 : Centre de Recherche Astrophysique de Lyon

Direct imaging has been shown as a powerful technique in exoplanet and circumstellar disk detection, yet there are still many challenges to overcome due to huge contrast and small angular separation between the source of interest and its host star. In recent years, a number of advanced processing techniques have been developed to push the limits of the instruments. My talk will be about the exploitation of innovative post-processing algorithms, PACO and REXPACO, which were recently developed by our team, to data of the Very Large Telescope instrument SPHERE/ZIMPOL, with the aim to improve the contrast and reduce the biases, to perform the deepest possible search for circumstellar disks. The reconstruction of these complex structures in a context of very low signal-to-noise ratio can only be envisaged by a joint processing of all the available data as well as by the use of a sufficiently precise instrumental model based on the physics of data training.

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Deep Learning for addressing the issue of parametrization in inverse problems

Théo Santos[1, 2], Férréol Soulez[2], Thomas Bodin[1]

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The objective of inverse problems is to infer the parameters of a model from observations. These problems occur in various fields, including Geophysics and Astrophysics. Two broad strategies are typically employed to address inverse problems:

- Assigning a probability to each potential solution and exploring the distribution
- Defining an error function, and finding a unique model that minimizes it

Regardless of the strategy chosen, an essential consideration is the parametrization : how to effectively describe the model with a finite number of parameters. An ideal parametrization should satisfy the following criterias :

- Enable computationally efficient model simulation
- Being low-dimensional
- Mitigate highly non-linear relationships between the model and simulated data.
- Facilitate adherence to a set of realistic models
- Alleviate non-uniqueness of models fitting a given observation
- Preserve a suitable level of details

We propose a method that leverages deep learning to address the parametrization issue in inverse problems. Generative neural networks offer a mean to map a low-dimensional « latent space » distribution to a high-dimensional distribution, utilizing a training set taken from the high-dimensional distribution.

We employ a generative network to generate model representations, allowing for a straightforward parametrization (through the latent space) of the models.

We illustrate this approach through two specific problems taken from different fields:

- Downscaling seismic tomographic images
- Blind deconvolution of astrophysical images

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Urban Dark Fiber Distributed Acoustic Sensing for Bridge Monitoring

Julie Rodet[1], Benoît Tauzin, Mohammad Amin Panah, Philippe Gueguen, Olivier Coutant, Destin Nziengui Bâ, Stephane Brule

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Distributed Acoustic Sensing (DAS) technology applied to telecommunication fiber optic networks offers new possibilities for Structural Health Monitoring (SHM). The dynamic responses of five bridges are extracted along a 24 km long optical fiber crossing the Lyon metropolitan area in France. From their characteristic seismic signatures, three physical parameters informing on the health of structures have been determined: vibration frequencies, damping and modal shapes. The fiber measurements are in agreement with velocimetric data serving as reference. The telecom optical fiber records the dynamic response of bridges in several directions and thus allows the reconstruction of 3D deformation modes using their orthogonality properties. Time tracking of frequencies, commonly used to assess structural integrity, shows that the average values of natural frequencies vary cyclically between day and night. The increase in frequencies during the night does not exceed 2% and probably reflects an overall stiffening of the structures due to the drop in temperature. The telecom fiber allows to obtain deformation and damping identity of structures, highlighting soil-structure coupling between the bridge and underlying soil. This study shows that it is possible to assess the spatial and temporal variability of bridge dynamic response from DAS data using existing fiber networks.

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Session D

GEOCHEMISTRY

À la table des Incas : le menu des enfants sacrifiés dévoilé par la géochimie isotopique
Eve Poulallion

Etude des pratiques de l'allaitement et du sevrage chez les grands singes via l'analyse isotopique de leurs dents
Danaé Guiserix

À la table des Incas : le menu des enfants sacrifiés dévoilé par la géochimie isotopique

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L'Empire Inca a émergé au XIIIe siècle à Cusco dans l'actuel Pérou. À son apogée, son territoire s'étendait sur l'ensemble de la côte ouest de l'Amérique du Sud. La chute de l'Empire Inca sera précipitée en 1532 avec l'arrivée des conquistadors espagnols. Les Incas étaient des individus très croyants qui pratiquaient de nombreux rites, notamment celui de la Capacocha impliquant le sacrifice d'enfants. Les enfants étaient sélectionnés un an avant leur sacrifice et leur régime alimentaire était alors modifié. Pendant cette année, ces derniers réalisaient un pèlerinage dans tout l'Empire avant d'être sacrifiés sur les montagnes sacrées. Nous avons étudié la momie d'une enfant sacrifiée au sommet du volcan Quehuar, dans la région de Salta, en Argentine. Afin de déterminer si le rituel était aussi codifié que décrit dans la littérature, nous avons souhaité comprendre les habitudes de vie de l'enfant avant son sacrifice, notamment concernant ses habitudes alimentaires. Nous avons mesuré les valeurs δ13C, δ15N et δ34S dans la kératine d'une mèche de cheveux. Ces mesures incrémentales permettent d'étudier les variations d'alimentation. En combinant ces trois proxys, nous avons proposé que les algues constituaient une proportion significative (» 16,2%) du régime alimentaire, hypothèse proposée pour la première fois.

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Etude des pratiques de l'allaitement et du sevrage chez les grands singes via l'analyse isotopique de leurs dents

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L'étude des comportements d'allaitement des populations humaines anciennes ou des hominidés fossiles est une problématique anthropologique et archéologique importante. En effet, connaître l'âge au sevrage d'une espèce ou d'une population renseigne sur le soin apporté aux jeunes, donne des indications sur l'alimentation de la population, et peut également donner une estimation de l'intervalle temporel entre les naissances. Il est cependant difficile d'accéder à cette information lorsque les seuls objets d'étude à disposition sont des restes fossiles, comme dans le cas des hominidés anciens. L'analyse géochimique des os et des dents est alors un outil essentiel pour répondre à ces problématiques. En effet, la signature isotopique de ces tissus dépend en particulier de l'alimentation de l'individu. Les systèmes isotopiques du calcium ($\delta^{44}Ca$), du zinc ($\delta^{66}Zn$) et du strontium stable ($\delta^{88}Sr$) sont déjà utilisés pour caractériser des différences d'alimentation et de niveau trophique. La signature isotopique du calcium dans le lait est de plus très différente de celle de l'alimentation adulte (viande et végétaux), ce qui suggère que la consommation de lait pourrait être enregistrée dans la signature isotopique du calcium des dents, puisque celles-ci se forment au début de la vie des individus. Afin de vérifier cette hypothèse, nous avons mené des analyses isotopiques du calcium, du strontium, et du zinc, dans des dents de chimpanzés et de gorilles modernes. Les résultats obtenus confirment le lien entre signature isotopique du calcium dans les dents et allaitement, et permettent de mettre en évidence des différences de pratique de sevrage entre ces deux espèces et Homo sapiens.

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Session F

PALAEONTOLOGY

Letting fossil birds talk about deep time seasonal migrations: an isotopic and histological approach
Anaïs Duhamel

Voay robustus, histoire d'un subfossile controversé : implications de l'anatomie endocrânienne et des datations radiocarbone à la biogéographie des crocodiles de Madagascar
Gwendal Perrichon

The oldest African echinoderms (Morocco): morphology and implications for the diversification of blastozoans in the early Cambrian
Christophe Dupichaud

Letting fossil birds talk about deep time seasonal migrations: an isotopic and histological approach

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Bird migration is a massive consequence of climate seasonality on wildlife, but its evolution through deep time – studied almost exclusively from extant bird data – is still poorly understood. In order to decipher and constrain the origin and evolution of bird migrations in time and space, there is an undeniable need for concrete snapshots of migratory behaviour through geological time, which only fossil material can provide, but such evidence is still lacking.

Given that the oxygen isotope fractionation of rainwater shows a climate-dependent latitudinal gradient, we hypothesise that the isotopic signature of oxygen in bone tissues (δ18Op) – derived from drinking rainwater isotopic composition and often unaltered during fossilisation – may be a good predictor of bird migratory behaviours. This was evaluated in the present study, comparing both simulated (for GPS-tracked birds) and experimental (for extant and fossil bird species) δ18Op of bone tissues mineralised in different contexts: during the growth of the bird at its breeding site (EB, early bone tissues) vs. during its adult life (LB, late bone tissues).

We highlight that: (i) among birds found in a temperature-dominated climate, only migratory birds are likely to have a significantly higher δ18O – typical of warmer temperatures – in LB tissues than in EB tissues; (ii) among birds found dead at the same site, only migratory birds born relatively far from the site are likely to have a δ18Op,EB outside the δ18Op,EB range defined by sedentary and juvenile birds born nearby. Applied to well-preserved fossil specimens, we illustrate that the above reasoning leads to convincing predictions of deep-time migratory behaviours, which, remarkably, represent the earliest concrete evidence for seasonal migration in birds to date (Early Miocene).

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Voay robustus, histoire d'un subfossile controversé : implications de l'anatomie endocrânienne et des datations radiocarbone à la biogéographie des crocodiles de Madagascar

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La diversité des crocodiles à Madagascar durant l'Holocène fut longtemps considérée comme uniquement représentée par l'espèce éteinte *Voay robustus* Grandidier & Vaillant 1872, l'île n'ayant supposément été colonisée que très tardivement par le Crocodile du Nil. Cependant, de récentes découvertes ont remis en cause cette hypothèse : en effet, les dernières datations au 14C indiquent que les populations de *Crocodylus* et *Voay* coexistaient depuis au moins 5600 ans avant notre ère (Martin *et al.*, 2022). Dans cette étude, nous présentons l'anatomie interne de *Voay* examinée au µCT-scan, montrant de nouvelles informations anatomiques permettant de distinguer *Voay* de *Crocodylus*. Les modèles 3D du cerveau et des sinus sont quantifiés en morphométrie géométrique pour repérer statistiquement les différences morphologiques entre ce fossile et une base de données de crocodylidés actuels. Enfin, de nouvelles données radiocarbones, associées à des enregistrements historiques du XIXIème et XXème siècle, sont utilisées pour préciser temporellement la cohabitation des deux espèces malgaches durant la fin du Quaternaire. Les informations endocrâniennes couplées aux données temporelles et géographiques permettent de soulever des hypothèses sur la différenciation écologique des deux espèces et de proposer des scénarios probables d'extinction. Ces approches s'additionnent aux précédentes études taxonomiques et phylogénétiques, révélant une image plus complète de la dynamique des changements fauniques à Madagascar.

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The oldest African echinoderms (Morocco): morphology and implications for the diversification of blastozoans in the early Cambrian

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Since their first appearance in the fossil record (Cambrian Stage 3, ~520 Ma ago), echinoderms were already relatively diverse (classes Edrioasteroidea, Eocrinoidea, Helicoplacoidea, and Lepidocystoidea) and cosmopolitan. This suggests a possible earlier origin of the phylum, although no evidence for this has been found due to the absence of Lagerstätten able to preserve non-mineralized ancestral forms. The major diversification of echinoderms during the Cambrian and Ordovician (about twenty classes, so four times the number of extant classes) renders particularly difficult the identification of homologous structures and the making of a phylogeny encompassing the whole phylum. The goal of this study is to clarify whether feeding appendages of blastozoans (brachioles) and crinoids (arms) are homologous (or not), and thus if those two groups belong (or not) to a same clade Pelmatozoa. In this context, the gogiid genus Alanisicystis -the oldest echinoderm known so far from the African continent, situated in Western Gondwana- is of particular interest. Its morphology was analyzed based on abundant and remarkably preserved specimens from the Issafen Formation (Cambrian Series 2, Stage 3; Morocco). This eocrinoid has a short stem composed of small, irregularly arranged circular plates. The theca is made of a mosaic of irregularly polygonal plates, ornamented with a fine granulation and numerous respiratory structures (epispires). Its aboral end consists of a single basal plate. The brachioles consist of two series of alternating flooring plates and two series of alternating cover plates. Those long appendages branch from the adoral end of the theca, at the edges of the oral frame.

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