Master Thesis Proposals

2024-2025

Space Sciences

Faculty of Sciences

Liège University

Important notice!

The present catalogue is especially relevant for master theses in the ***Research focus***.

Its content **is not exhaustive**, and students are encouraged to contact specific teachers/researchers to ask them about potential alternatives if they are interested in other topics.

For the ***Professional focus***, the master thesis must mainly consist of an internship and there is no specific offer prepared in advance. Students are encouraged to search for opportunities out of the AGO Department. To do so, contacting other institutes is highly recommended, including

- Liège Space Centre (Sart-Tilman) : http://www.csl.uliege.be (or via S. Habraken, M. Georges)
- Belgian Institute for Space Aeronomy (Brussels) : http://www.aeronomie.be/en/
- Royal Observatory of Belgium (Brussels) : https://www.astro.oma.be/en/
- Royal Institute for Meteorology (Brussels) : https://www.meteo.be/en/
- The AMOS company (Sart-Tilman) : https://www.amos.be/
- The Aerospacelab company (Mont-Saint-Guibert): https://www.aerospacelab.be/

… or any other company involved in space activities.

About master theses out of ULiège...

Students involved in internships (abroad, in Belgium, and even at the Centre Spatial de Liège) have to fill in an internship agreement and a risk analysis sheet. These documents must be completed in consultation with the person responsible for the internship at the host institution, with the agreement of the teacher/academic supervisor in ULiège.

For any question or request for assistance, the contact person for the Faculty of Sciences is Mrs Kristel Karremans: Kristel.Karremans@uliege.be

In addition, for a stay abroad it is mandatory to follow an on-line procedure to officially request the authorization to the Rector of the University (MODUS platform). This is necessary for the validation of the activity abroad in the student's master program and for benefiting of an insurance coverage. The request should be introduced at least one month (sooner is better!) before the expected date of departure.

Astroparticles, Dark matter and Gravitational waves

Contact person : J.R. Cudell (IFPA)

e-mail : jr.cudell@uliege.be

Tel : 04 366 3654

Office: 4/44 (B5a)

Availability: most afternoons in May or June. Check via e-mail if you want to be sure,

Thematics : Cosmology and astroparticles

Description:

A number of possibilities exist (in particle physics, astroparticle physics, dark matter, gravitational waves,…), and I encourage interested students to come and see me.

Galaxy clusters' strong gravitational lensing with Euclid - Automating the lensed galaxies' detection and modelling to answer questions about the nature of Dark Matter

Contact person : Guillaume Mahler (MEGA)

e-mail : Guillaume.mahler@uliege.be

Tel : --

Office : B5a 1/11

Availability : from the 6/05 to the 31/05 & from the 18/06 to the 28/06

Thematics : Cosmology; Astrophysics; Extra-galactic; Gravitational lensing

Description : In the prevailing picture of cosmology, roughly 80% of the mass in our Universe exists as dark matter. Although we have never observed dark matter directly, we can still indirectly detect its presence through its gravitational interaction with visible (baryonic) matter. As some of the largest and most massive structures in the Universe, galaxy clusters are the largest reservoirs of dark matter, making them ideal laboratories for studying the properties of this mysterious substance.

While several techniques exist for characterising cluster dark matter content, gravitational lensing remains one of the most powerful. This is because lensing provides a detailed mapping of total cluster mass through a simple observable: the apparent deflection of distant light rays (originating from e.g. a background galaxy) as they pass by a massive foreground object (e.g. a nearby galaxy cluster). After revealing this total mass map, further analysis separates the baryonic content, leaving a clean picture of the dark matter.

In this project we will focus on the core of galaxy clusters, where the deflections are large and create multiple-images of a same background galaxy. The advent of new observatories, such as the spatial telescope *Euclid* will increase the number of known lenses by nearly two orders of magnitude more, going from 100s to 10,000. The expert visual inspection traditionally used to discover lenses is incapable of reducing these data deluge (e.g. Nord et al 2016). It is important to create the necessary tools to deal with this upcoming overflowing data, and create automated algorithms to unlock scientific discoveries.

One of the key step to the modelling of clusters and therefore mapping their dark matter content in this context is automating the identification of multiply-imaged gravitationally lensed galaxies. The project tackle in this thesis will be to come up with a software solution to this problem and applying it to the large number of clusters observation. Following this development the application fo this identification to cluster modelling should yield strong constraints on dark matter properties and notably it's cross-section. Indeed at the core of cluster models with large dark matter cross section predicts a rounder and flatter profil. So far individual cluster analysis or small ensemble of clusters have been able to yield competitive results.

This work could constitute a first step before a PhD thesis related to clusters formation and dark matter properties.

Prerequisites: Experience with python programming (e.g. via SPAT0002-1: Programming techniques, numerical methods and machine learning) is needed. Other recommended courses: Extragalactic astrophysics (SPAT0011-1) or Cosmology (SPAT0012-1).

Dark matter and stellar mass co-evolution in the densest node of the Universe observed by the James Webb Space Telescope

Contact person : Guillaume Mahler (MEGA)

e-mail : Guillaume.mahler@uliege.be

Tel : --

Office : B5a 1/11

Availability : from the 6/05 to the 31/05 & from the 18/06 to the 28/06

Thematics : Cosmology; Astrophysics; Extra-galactic; Gravitational lensing

Description :

Clusters of galaxies are powerful cosmological probes sampling the high end of the mass function of collapsed structures, offering stringent tests of the structure formation paradigm in our Universe. JWST observations drawn from a large Sunyaev-Zel'dovich (SZ) and X-ray-selected cluster sample offers an ideal, well-understood selection function to study their evolution. Some of these clusters present strong gravitational lensing events.

While several techniques exist for characterising cluster dark matter content, gravitational lensing remains one of the most powerful. This is because lensing provides a detailed mapping of total cluster mass through a simple observable: the apparent deflection of distant light rays (originating from e.g. a background galaxy) as they pass by a massive foreground object (e.g. a nearby galaxy cluster). After revealing this total mass map, further analysis separates the baryonic content, leaving a clean picture of the dark matter.

The cores of galaxy clusters are the dynamic locations where violent physical processes generate radical transformations that hold valuable cosmological information and critical information about its complex history. *JWST's* unique resolution, sensitivity, and Infrared capabilities allow us to now probe the (mostly old) stellar content of galaxy clusters at high redshift.

Equipped with dark matter mapping and characterisation of the stellar light within a large number of clusters we can now track the co-evolution of stellar and dark matter mass within clusters over cosmic time. The project will focus on stellar mass characterisation and/or dark matter mapping and aim to combined the two to better understand the cluster formation history.

This work could constitute a first step before a PhD thesis related to clusters formation and dark matter properties.

Prerequisites: Experience with python programming (e.g. via SPAT0002-1: Programming techniques, numerical methods and machine learning) is needed. Other recommended courses: Extragalactic astrophysics (SPAT0011-1) or Cosmology (SPAT0012-1).

Gravitational microlensing by primordial black holes

Contact person : Guillaume Mahler & Dominique Sluse (MEGA)

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Tel : --

Office : B5a 1/11 & B5a 1/10

Availability : from the 6/05 to the 31/05 & from the 18/06 to the 28/06

Thematics : Cosmology; Astrophysics; Extra-galactic; Gravitational lensing

Description :

Large separation gravitationally lensed quasars are rare systems constituted of quasar images separated on the sky by several tens of arcseconds. They are generally found behind strong lensing clusters of galaxies which produce multiple images of a background quasar and of other distant galaxies. Because of these characteristics, the line-of-sight towards those lensed images is expected to be dominated by dark matter. If a small fraction of the dark matter is constituted of primordial black holes, or if low mass dark matter "clumps" are present, one may expect microlensing to occur and modify the apparent brightness of the background lensed image. This master thesis aims at forecasting microlensing by primordial black holes in known large separation systems. The impact of the source size on the expected occurrence of microlensing will also be studied.

These forecasts may be compared to real data. For several systems, it is possible to derive observational constraints on the presence of microlensing from spectra and lightcurves of lensed images available in the group or in the literature. This work could constitute a first step before a PhD thesis related to microlensing.

Prerequisites: Experience with python programming (e.g. via SPAT0002-1: Programming techniques, numerical methods and machine learning) is needed. Other recommended courses: Extragalactic astrophysics (SPAT0011-1).

X-ray emission in a short period interacting wind eclipsing massive binary

Contact persons: Gregor Rauw & Yaël Nazé, High-Energy Astrophysics Group

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Tel: 04/366 9740

Office: Institut d'Astrophysique & Géophysique, Bât B5c, Allée du 6 Août, 19c, room 2/2

Availability: interested students are invited to contact the coordinator by e-mail to arrange an appointment

Thematics: stellar astrophysics, X-ray astrophysics

Description:

The majority of massive OB-type stars reside in binary or higher multiplicity systems. As these stars feature highly energetic stellar winds, the collision between those winds is expected to generate a strong and relatively hard X-ray emission. Furthermore, the level of observable X-ray emission is expected to vary with orbital phase as the stars revolve around their common centre of mass. Yet, detailed investigations with modern X-ray satellites showed that many O-star binaries, especially those with short orbital periods, lack a strong X-ray emission and rather display a level of emission that is consistent with the typical intrinsic emission arising from the individual winds (i.e., without any significant additional emission from a wind-wind collision). We propose here to investigate the X-ray properties of a well-known eclipsing O-star binary observed with XMM-Newton at several orbital phases.

The student is asked to:

- get acquainted with the properties of the target stars and with the general subject of wind interactions in massive binaries,
- process all available XMM-Newton observations of the target system,
- analyse the EPIC and RGS spectra using the xspec software,
- establish the variations of the X-ray emission as a function of orbital phase, and compare them with ROSAT data
- and finally, discuss the results obtained, compare them with what is observed in other colliding wind binaries, and discuss the implications.

Remarks: attending or having attended the course on “High-Energy Astrophysics” is clearly an advantage.

Line profile variability in peculiar massive stars

Contact persons: Gregor Rauw & Yaël Nazé, High-Energy Astrophysics Group

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Tel: 04/366 9740

Office: Institut d'Astrophysique & Géophysique, Bât B5c, Allée du 6 Août, 19c, room 2/2

Availability: interested students are invited to contact the coordinator by e-mail to arrange an appointment

Thematics: stellar astrophysics

Description:

Some massive OB-type stars display variations of their spectral lines that hint either at (non-radial) pulsations at their surface or structures inside their circumstellar environment. Studying these phenomena opens new avenues to learn more about the fundamental properties of these stars. Indeed, the properties of pulsations reflect the internal structure of the star, whilst the structures in the circumstellar environment bear information about its dynamics and the possible impact of a companion star on this environment. Observationally studying these phenomena requires long series of high-quality spectroscopic observations. Over recent years, our team has collected such data for several peculiar massive stars.

The student is asked to

- get acquainted with the properties of the target stars and with the general subject of spectral line profile variability in massive stars,
- normalize and analyse the spectroscopic observations that have been collected for the target stars,
- apply a series of tests to the time series of spectra of each of the stars to search for variability, specify its significance level and to establish possible periodicities,
- and finally, compare the results with what is known about the targets in the literature and discuss the implications of the results.

Remarks: attending or having attended the course on “Variable Stars” is clearly an advantage.

High-energy variability of a single massive star

Contact person: Yaël Nazé & Gregor Rauw, High-Energy Astrophysics Group

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Office: Institut d'Astrophysique & Géophysique, Bât B5c, Allée du 6 Août, 19c, room 2/12

Availability: interested students are invited to contact the coordinator by e-mail to arrange an appointment

Thematics: stellar astrophysics, high-energy astrophysics

Description:

Massive OB-type stars emit X-rays thanks to shocks arising in their winds. The recorded X-ray characteristics therefore sensitively depend on the wind properties. In this project, the direct link between winds and X-rays will be investigated in detail thanks to high-quality data acquired by space telescopes.

The student is asked to

- get acquainted with the properties of massive stars at high energies and the general knowledge of the target,
- process X-ray data of the target, to build spectra and light curves,
- analyze these spectra and light curves, and assess their variability,
- and finally, compare the results with the known target variability at other wavelengths and discuss the results and their implications.

Remarks: attending or having attended the course on “High Energy Astrophysics” is clearly an advantage.

Following a magnetic interaction in X-rays

Contact person: Yaël Nazé & Gregor Rauw, High-Energy Astrophysics Group

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Office: Institut d'Astrophysique & Géophysique, Bât B5c, Allée du 6 Août, 19c, room 2/12

Availability: interested students are invited to contact the coordinator by e-mail to arrange an appointment

Thematics: stellar astrophysics, high-energy astrophysics

Description:

While magnetic features can be found on (nearly) all low-mass stars, only a small fraction of massive OB-type stars display magnetic fields. These fields are very different in nature from those of low-mass stars. For massive stars, the fields are strong, dipolar, and rather constant. In parallel, massive stars also emit strong winds, and this ionized material will of course interact with any magnetic field. If the magnetic field is strong enough, the wind outflows are forced to follow magnetic field lines, leading to regions of enhanced density close to the magnetic equator. The shocks in this material also result in a very specific X-ray emission. This project proposes to follow the interaction between field and wind at these high energies, to pinpoint the magnetospheric behaviour.

The student is asked to

- get acquainted with the properties of magnetic stars, in particular those of the target itself,
- process X-ray data of the target, to build spectra and light curves,
- analyze these spectra and light curves, and assess their variability as a function of phase,
- and finally, compare the results with what is known about the target in the literature and discuss the results and their implications.

Remarks: attending or having attended the course on “High Energy Astrophysics” is clearly an advantage.

Transitory convective cores in low metallicity stars

Contact person : Gaël Buldgen & Marc-Antoine Dupret (ASTA)

e-mail : gbuldgen@uliege.be; ma.dupret@uliege.be

Tel : **+32 4366 9732**

Office: B5c, room 1/12

Availability: Anytime in May or June, but please contact us before for convenience

Thematics : Astrophysics: stellar physics, asteroseismology

Description:

Context: The modelling of convection is one of the most uncertain aspect in the theory of stellar structure and evolution. The shortcoming of the currently used simplified theories lead to uncertainties regarding extra-mixing processes acting at the border of convective layers. In the case of stellar cores, additional mixing at the border of convective layers is considered to be the main driver of uncertainties on stellar ages, often associated with stars above 1.2 solar masses. However, another physical regime leads to the apparition of fully-mixed cores in the early evolutionary stages of all solar like stars, linked with the out-of-equilibrium burning of Helium 3. Constraining the properties of such cores can only be achieved using new seismic indicators in the era of high-quality space-based photometric surveys.

Method: The student will be introduced to the Liège Stellar Evolution Code (CLES) and to the Liège Adiabatic Oscillation Code (LOSC). Grids of models will be computed with CLES to study the apparition of convective cores due to out-of-equilibrium burning of Helium 3 and their evolution with time. Oscillation frequencies will be computed to determine whether some well-chosen seismic indicators may provide a hint of the detectability of these cores, as well as the characterize their size or duration of their lifetime. The study will be purely theoretical and involve detailed analysis of the internal structure of low mass stars (between 0.8 and 1.1 solar masses)

Recommended courses: Stellar structure and evolution I SPAT0044-1 (& II SPAT0045-1) & Stellar stability and asteroseismology SPAT0005-1 (Pr. M-A Dupret)

Dynamical tides and orbital evolution of heartbeat stars

Contact person : Marc-Antoine Dupret (ASTA)

e-mail : MA.Dupret@uliege.be

Tel : 04 366 97 32

Office: B5c, room 1/12

Availability: Anytime from May to mid-July

Thematics : Astrophysics: stellar physics

Description:

Context:

Binary systems are very frequent in the stellar world, which can involve tidal interactions when the components are close enough. Tides deform the shapes of stars and thus modify their observable characteristics. In very eccentric binary systems, the tidal deformation is very strong at each periastron passage, taking the form of so-called dynamical tides. The observational signature of this phenomenon is similar to an electrocardiogram, which lead the scientific community to name them heartbeat stars. These dynamical tides can enter in resonance with free oscillation modes, leading to large amplitude tidally excited oscillations. These resonances in turn have a major impact on the evolution of the orbital parameters of these systems: pseudo-synchronization processes, … Resonance locking can also occur in some cases.

Proposed work:

We have just developed in our team a new model of dynamical tides including for the first time a full account of the energetic aspects and the Coriolis force. We propose in this thesis to apply it to heartbeat stars. The student will model with this tool tidally excited oscillations of different types, with a special focus on the impacts of fast rotation and vibrational instabilities. Next, he will model the impact of the resonances with different types of modes on the evolution of the angular momentum of typical models of heartbeat stars.

Recommended courses: SPAT0045-1 Stellar structure and evolution I and II & Stellar stability and asteroseismology SPAT0005-1

Seismic probing of chemical mixing in the core of γ Dor stars observed by the Kepler space mission

Contact person : Martin Farrnir & Marc-Antoine Dupret (ASTA)

e-mail : martin.farnir@uliege.be; ma.dupret@uliege.be

Tel : +32 4366 9765/9732

Office: B5c, room 1/14 or 1/12

Availability: Anytime in May or June, but please contact us before for convenience

Thematics : Astrophysics: stellar physics, asteroseismology

Description:

Gamma Doradus stars are main-sequence A and F-type stars presenting high-order gravity modes of pulsations. Some of them present a hybrid-pulsator character by also showing pressure modes, known as δ Scuti variability. For a while, the periods (a few hours) and amplitudes (a few mmag) of their pulsations made them hardly detectable from ground-based observatories. Yet, the Kepler space telescope, with its long and uninterrupted observing campaigns, revealed rich and complex stellar pulsation spectra in hundreds of γ Dor stars. As these stars evolve, their convective cores shrink, leaving behind a sharp gradient in chemical composition. Such sharp features leave traces in the pulsation frequencies displayed by the γ Dor stars. Indeed, the inherently regular pattern in individual mode's periods is perturbed by the presence of the sharp structural feature producing an oscillating pattern. Consequently, measuring and characterising this oscillatory signature represents a unique opportunity to characterize the sharp feature from which it originates (sharpness and amplitude) and measure its depth. This is very important as it would allow to constrain the deep chemical transport processes continuously alimenting the core with fresh hydrogen (e.g. overshooting, turbulent mixing due to rotation), which are part of the main sources of uncertainty in current stellar models.

Within the ASTA team, we have developed several tools to compute and analyse seismic data of main sequence stars. Using key quantities measurable from the oscillation spectrum, called seismic indicators, the motivated student will study their theoretical relation with the stellar structure (using stellar models) and the impact of the mixing prescriptions. Depending on the motivation of the student and his/her scientific affinities, he/she will determine novel approaches to directly measure these indicators and/or implement modifications in our existing tools to enable the efficient retrieval of these indicators from observed oscillation spectra.

Recommended courses: Stellar structure and evolution I SPAT0044-1 (& II SPAT0045-1) & Stellar stability and asteroseismology SPAT0005-1 (Pr. M-A Dupret)

Investigating the properties of the galactic population of pulsars based on radio light curves

Contact person : Michaël De Becker (MEGA)

e-mail : Michael.DeBecker@uliege.be

Tel : 04 366 9717

Office: 1/8, 1st floor of building B5c

Availability: Please send an e-mail to organize an appointment

Thematics : Astrophysics

Description:

There are more than 3,500 known pulsars in the Milky Way galaxy. Most of them are revealed by their typical radio light curve, which shows clear pulses with a time interval corresponding to their rotation period.

Within the framework of the standard model for pulsar radio emission, the measurement of light curves of pulsars can be used to determine some of their main properties, such as the lower limit of their magnetic field, their lifetime and their braking index. An important part of the thesis will be a critical discussion of the distribution of parameters characterising the population of Galactic pulsars. The discussion should also include a significant bibliographic component.

This Master's thesis topic requires the processing of data collected in the main pulsar catalogue using tools that will be developed by the student. To this end, any interested student should express some affinity for programming (with any language of their choice).

Recommended courses:

SPAT0069-1 Radio astrophysics

SPAT0002-1 Statistical methods and data analysis

Exploring the molecular content of interstellar clouds using astrochemical models

Contact person : Michaël De Becker (MEGA)

e-mail : Michael.DeBecker@uliege.be

Tel : 04 366 9717

Office: 1/8, 1st floor of building B5c

Availability: Please send an e-mail to organize an appointment

Thematics : Astrophysics

Description:

With more than 300 different molecules identified in dense interstellar clouds, the study of interstellar physico-chemical processes has become a major research theme in astrophysics. The investigation of these astrochemical processes involves considerations about the interplay between molecular processes and large-scale, astrophysical conditions.

The core of this master thesis consists in the study of interstellar clouds from an astrochemical perspective, using models that allow us to follow the evolution of real abundances of multiple species over time, and to identify the main routes of molecule formation.

The first stage of the work will involve familiarising with the appropriate modelling tools. The student will also be free to define, in discussion with the supervisor, which aspect of interstellar physical chemistry will be developed in the master's thesis.

The student will also carry out an extensive bibliographical exploration with a view to ensuring a good connection between his work and the research being carried out in this area.

Required courses:

SPAT0020-2 Astrochemistry

Recommended course:

SPAT0008-1 Interstellar medium

Asteroid light curves from TRAPPIST telescopes archived images

Contact Person: Jehin Emmanuël (COMETA)

e-mail: ejehin@uliege.be

Tél: (0)4 3669726

Office: B5c 1/9

Availability: please contact me

Thematics: Astrophysics (small bodies of the solar system)

Description:

The TRAPPIST telescopes installed at the la Silla observatory in Chile in 2010 and at the Oukaimeden observatory in Morocco in 2016 by our team are dedicated to the research and the study of exoplanets in transit and the study of the small bodies of the Solar System (comets and asteroids). Each night, since 15 years in Chile and 10 years in Morocco we collect hundreds of images of one or two fields during several hours to search for exoplanets in transit. This constitutes a unique dataset of about 2.5 million images to be explored to search for asteroids and comets.

In this work we propose to search the huge database of TRAPPIST to identify the known asteroids present in the images using their well known orbits. As some fields are observed several nights in a row and for many hours per night it will be possible to build high density light curves for many of these objects and measure their rotation period.

Objectives: Find the known asteroid present in the TRAPPIST archive. Measure and collect the photometric measurements for each target found and build their light curves with time to try to find the asteroid rotation period. Most of these rotation light curves will be new and will be published in a paper. This will be useful to better understand the evolution of small bodies via Yarkovsky/YORP effect by comparing the distribution of the properties of spins (period, longitude, latitude) to the dynamical families.

This work will be done in collaboration with astrophysicists from the Nice Observatory who have developed a new pipeline for such work.

https://www.trappist.uliege.be/

https://www.cometa.uliege.be/

Study of the chemical composition of comets atmospheres using the TRAPPIST telescopes

Contact person: Jehin Emmanuël (COMETA)

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Office: B5c 1/9

Availability: please contact me

Thematic: Astrophysics (small bodies of the solar system)

Description:

Comets are among the best preserved specimens of the primitive solar nebula. This status of “fossils” gives them a unique role in understanding the origins of the solar system. The success of the Rosetta space mission was very important and is changing our knowledge about comets. But it showed also that observations from the ground continue to be important: they make it possible to supplement the data in situ by obtaining information on larger scales of the coma and tails, and for a much larger number of comets, which is necessary to extrapolate the results to the entire cometary population. The link between the composition of comets and their dynamic history must still be clarified and a complete comet classification is still missing.

In this context, we propose the observation and analysis of the coma of two or three bright comets with the TRAPPIST telescopes network. These robotic telescopes installed by our team in Chile (in 2010) and in Morocco (in 2016) are equipped with narrow band filters to isolate the emissions of different gases and dust contained in the atmosphere of comets. The student will have to prepare the observations, calibrate the data and calculate the production rates of the different gases using the so-called Haser model (1957). The necessary tools for this kind of measures have already been developed in our team. The student will have to become familiar with the various techniques, adapt and improve if necessary the reduction procedures and scripts and run the models. The results might lead to the publication of a short article.

The work will be done in the comet group of the COMETA Service (+1) and the TRAPPIST team

https://www.trappist.uliege.be/

https://www.cometa.uliege.be/

Determination of meteor parameters using radio head echoes from the FRIPON and BRAMS network

Contact person : Hervé Lamy (IASB) & Emmanuël Jehin (COMETA)

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Tel : 02/3730418

Office: BIRA-IASB, Avenue Circulaire 3, 1180 Uccle.

Availability: If possible a Friday, for example Friday 17, 24, 31 May or 7 June.

Thematics : Astrophysics; Planetology and planetary systems; Instrumentation and methods.

Description:

Radio observations of meteors are complementary of the more traditional optical observations carried out with networks of cameras. A transmitter emits a radio wave towards the sky which can be reflected by electrons created by the passing of a meteoroid in the upper atmospheric layers around 80-110 km altitude. The reflected signal, called a meteor echo, can be recorded by a receiving station which can be co-located (radar) or not (forward scatter system) with the transmitter. Most reflections occur on the ionized trail left behind the meteoroid (trail echo) but for bigger objects (typically cm-sized or larger), a reflection on the ionized part located in front of the object can also be detected (head echo). Both types of meteor echoes are affected by a Doppler effect since the ionized region is moving. For trail echoes, this displacement is due to upper atmospheric winds and are typically of 10-100 m/s. For head echoes, this Doppler Effect is stronger since the object is moving at much higher speed, typically 10-70 km/s.

Analysing data from head echoes can provide meteor parameters such as the speed of the meteoroid and its deceleration in the atmosphere. These can be obtained by combining data from several receiving stations and studying the shape of the signal in the frequency domain which is due to the Doppler Effect. Additional data could be obtained such as the detection of fragmentation along the meteoroid path.

In this master thesis, we propose to analyse data obtained with two radio networks: FRIPON-radio and BRAMS. FRIPON (Fireball Recovery and InterPlanetary Orbit determination) is a network of all-sky optical cameras dedicated to the detection and characterization of fireballs (very bright meteors) and the computation of their orbital parameters before they entered Earth’s atmosphere. Approximately 20 stations are also equipped with radio antenna and receivers and form the FRIPON-radio network, which was developed specifically to study meteor head echoes frequently observed with fireballs. The transmitter for this network is a French military radar called GRAVES, located near Dijon. One of the receiving stations is in Uccle, on the roof of BIRA-IASB. The transmitted power is very large (a few Megawatts) allowing to observe the meteor head echoes on a large frequency range. BRAMS (Belgian Radio Meteor Stations) is a network of ⟷50 radio receiving stations mostly located in Belgium and designed to study mostly meteor echoes. A dedicated transmitter is located in Dourbes. Head echoes are also usually detected by many stations for fireballs passing above or nearby Belgium. The main goal is to determine meteoroid speed from both data sets, and to compare the results also with those obtained from optical observations.

Characterizing auroral arcs in Jupiter's outer emissions

Contact person : Bertrand BONFOND (LPAP)

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Tel : 04 366 9772

Office: B5c 0/2

Availability: Please contact me via email.

Thematics : Planetology and planetary systems

Description:

Jupiter's ultraviolet aurorae are formed of three main regions. From the equator to the pole are: 1) the outer emissions, 2) the main emissions and 3) the polar emissions. Each of these regions are populated with different auroral features, each one of them arising from a different process. Four distinct kinds of features have been identified in the outer emissions: the satellite footprints, diffuse emissions, injection signatures and auroral arcs.

For this study, you will analyse observations from the Ultraviolet Spectrograph on board the NASA Juno spacecraft to identify and characterize the auroral arcs using automated procedures. You will determine the shape, length, width and colour of these features in order to unveil the mechanisms generating them.

Searching for waves on Jupiter's magnetopause

Contact person : Bertrand BONFOND (LPAP)

e-mail : b.bonfond@uliege.be

Tel : 04 366 9772

Office: B5c 0/2

Availability: Please contact me via email.

Thematics : Planetology and planetary systems

Description:

Jupiter has the largest magnetosphere of the solar system. The reason for this large size is both the intense internal magnetic field of the planet and the large internal plasma source that further inflates the magnetosphere. The latter is due to the outgassing and subsequent ionization of SO_2 from the volcanic moon Io. As a result of this additional source of inflation, the front of the magnetopause can be anywhere between 60 and 100 Jovian radii from Jupiter, depending on the strength of the solar wind dynamic pressure. Moreover, this highly variable magnetosphere is less prone to magnetic reconnection than the Earth's. However, the shear between the solar wind and the magnetospheric plasma can trigger Kelvin-Helmholtz instabilities which manifest as vortices which allow the transfer of momentum and sometimes particles across the magnetopause.

You will analyse the magnetic field measurements of the various probes that explored the Jovian magnetosphere, including the Juno spacecraft currently orbiting Jupiter, and you will determine the orientation of the normal to the magnetopause surface, looking for the signature of large-scale waves and vortices. All the data required for this analysis are archived on NASA's Planetary Data System.

The auroral UV emissions of the Galilean moons

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Availability: Please contact me via email.

Thematics : Planetology and planetary systems

Description:

The four large moons of Jupiter, named Io, Europa, Ganymede and Callisto, all have a thin atmosphere, arising either from volcanic outgassing (Io), or a mix of sputtering and sublimation of their icy surface (the three others). Because each moon interacts with the magnetospheric particles in a different manner, the complex interaction between the charged particles of the Jovian magnetosphere, the (induced or intrinsic) magnetic field of the moons and their atmosphere leads to dramatically different aurorae. In 2022, 2023 and then in 2024, the NASA Juno spacecraft has flown-by at relatively close distance from the Jovian moons Ganymede, Europa and finally Io. In this study, you will reconstruct maps of the UV auroral emissions observed during these exceptional encounters, based on the data from Juno's Ultraviolet Spectrograph. To do so, you will carefully analyse the geometry of the observations with respect with the trajectory and attitude of the spacecraft adapting existing codes relying on NASA's Navigation and Ancillary Information Facility (NAIF). This important exercise will serve as a preparation for similar encounters with the JUICE spacecraft arriving at Jupiter in 2031.

High-contrast imaging of protoplanetary disks with VLT/NACO

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Availability: In person: 13-14 May, 21 May, 27-28 May, and 10-11 June. Otherwise by telecon.

Thematics : Planetology and planetary systems; Instrumentation and methods

Description:

With over 15 years of operation and some of the first directly imaged exoplanets in its tally, NACO at the Very Large Telescope (VLT) has been one of the most prolific high-contrast imaging instruments to date. Image processing algorithms aiming to model and subtract the bright stellar halo in order to unveil faint circumstellar signals have significantly improved over time. Yet archival data have not been re-processed with the latest tools.

This project aims to leverage both the large archive of VLT/NACO observations and the latest developments in PSILab for optimal imaging of faint extended signals, with the goal of identifying new protoplanets in their birth environment. All relevant archival NACO data have been calibrated and preprocessed, and the application of new iterative algorithms based on principal component analysis, recently developed in PSILab, is now needed for optimal imaging of planet-forming disks at multiple epochs, in order to identify new protoplanets.

So far only the forming planets found in the disk around PDS 70 are unanimously considered as bona fide protoplanets. New detections and follow-up characterisation are crucially needed to provide observational constraints to giant planet formation models. The identification of new protoplanet candidates would motivate follow-up coronagraphic observations with NACO's successor, the ERIS instrument of the VLT, which achieves even better contrast performances at thermal infrared wavelengths thanks to its exquisite adaptive optics correction and its vortex coronagraph, developed and commissioned by ULiège (PSILab team). Multi-wavelength follow-up observations with VLT, ALMA, and potentially JWST, of any detected protoplanet would provide some of the most stringent constraints on the physical and accretion properties of protoplanets, and on the properties of circumplanetary disks — the birth environment of moons. Any new discovery as part of this project would thus have a significant impact.

This project involves an international collaboration with colleagues at ETH Zürich and MPIA Heidelberg, which are also part of this data mining effort.

Attending the courses SPAT0063 and SPAT0067 would be an asset to the success of this project.

Estimating the direct imaging exoplanet yield of VLT/ERIS

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Availability: Weeks of 13-17 May, 27-31 May, 10-14 June, and 24-28 June

Thematics: Planetology and planetary systems; Instrumentation and methods

Description:

The Enhanced Resolution Imager and Spectrograph (ERIS) is the latest addition to the instrumentation suite at the Very Large Telescope (VLT). The observational modes ERIS provide among others high-contrast imaging with a thermal infrared (3-5µm) vortex coronagraph developed and commissioned by ULiège (PSILab team). Thanks to its high throughput and wide discovery space, the vortex coronagraph stands out as the go-to option to implement dedicated imaging surveys for exoplanets with ERIS in the coming years. Such surveys would however only be considered for implementation if they are shown to provide a significant improvement compared to what other instruments have been doing at shorter wavelengths in the past, including the SPHERE near-infrared high-contrast imager at the VLT, or the NIRCam camera onboard the James Webb Space Telescope (JWST). One potentially decisive advantage of the ERIS vortex coronagraph is its operating wavelength (around 4 µm), at which self-luminous young planets are expected to be significantly brighter. A well-targeted exoplanet survey with ERIS could then provide much-needed constraints on the outcome of planetary formation, by probing orbital distances that cannot be accessed with indirect exoplanet detection techniques such as radial velocity and transits.

The main goal of this project is to assess the performance and potential yield of ERIS for future exoplanet surveys. The main tasks to reach this goal are the following:

- From the commissioning and early scientific data obtained with ERIS, consolidate the instrument's estimated sensitivity to faint off-axis companions around bright stars, using standard high-contrast data processing tools (this information may already be largely available by the start of the masters project);
- Define a target population of relatively young stars, and use publicly available planet formation models to estimate the number of giant planets present around these stars;
- Estimate the contrast between the target stars and their planetary companions using publicly available exoplanet evolution models, which predict the brightess of an exoplanet as a function of its mass and age;
- Infer the potential yield of ERIS in terms of detected planets for the considered stellar population, and possibly adapt the target star sample based on these results;
- Compare the estimated ERIS yield with the expected yield of VLT/SPHERE and JWST/NIRCam on the same stellar population, using a similar methodology.

Ideally, the final product of this project would be the preparation of a convincing and well-justfied observing proposal that could be submitted to ESO for implementation on ERIS.

Attending the courses SPAT0063 and SPAT0067 would be an asset to the success of this project.

Adsorption Processes in MEDUSA

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Availability: by appointment

Thematics: climate, environment and oceanography

Description:

Solute transport in porous media such as seafloor surface sediments is mostly by molecular or ionic diffusion in porewater. However, for some nutrients, such as ammonium or phosphate ions, transport by adsorption onto solid particles is another important mechanism.

Adsorption processes are currently not represented in the Model of Early Diagenesis in the Surface Sediment with Adaptable complexity, MEDUSA (Munhoven, 2021). While a reasonably realistic steady-state representation of adsorption processes (by diffusion coefficient enhancement) can be realised by code patching, it is unclear if this approach allows for selective adsorption on special types of solid particle (e. g., clay particles only). As a result, it would be more consistent to extend the code generator to allow for the explicit inclusion of adsorption processes.

Here, I propose to implement both approaches in MEDUSA and to perform a comprehensive sensitivity analysis of the two methods, and of the relative importance of transport by adsorption in general.

Requirements and prerequisites This thesis project requires advanced programming skills. The code generator for MEDUSA is written in Fortran 95 and needs to be adapted. Introductory training in Fortran 90/95 can be provided if required.

Basic knowledge of biogeochemical cycles (carbon, phosphorus, nitrogen) would be useful, but is not indispensable, as this can be easily acquired from textbooks and scientific literature (rich collection available in the lab).

Infrastructure Usual developments and test simulations can normally be done on the student’s own computing devices (laptop, desktop PCs), but a calculation server is available in the lab if required.

Stays abroad This work can be completely done in Liège.

Carbon Dioxide Removal with MBM-MEDUSA
(or *i*LOVECLIM-MEDUSA)

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Availability: by appointment

Thematics: climate, environment and oceanography

Description:

As a result of the painfully slow progress in reducing CO_2 emissions to the atmosphere, Carbon Dioxide Removal (CDR) has over the years become a confirmed ingredient in the cocktail of measures to take in order to reduce atmospheric CO_2: fulfilling the requirements of the Paris agreement, i. e, keeping the mean global warming well below 2 °C above pre-industrial levels, and preferably below 1.5 °C by the year 2100, will at this stage require some form of CDR. CDR encompasses all kinds of processes that remove CO_2 from the atmosphere, be this by afforestation or reforestation, bioenergy with carbon capture and storage (BECCS), direct air capture and storage (DACS) or ocean alkalinization. The overall efficiency of CDR methods is, however, subject to debate: it appears that positive emissions are more efficient in increasing global temperature than negative emissions in decreasing them.

Here, I propose to adapt the coupled ocean carbon cycle-sediment model MBM-MEDUSA (Munhoven, 2007, 2021) so that it can be used to carry out the standard experiments of the Carbon Dioxide Removal Model Intercomparison Project (CDRMIP). The analysis will then also focus on the impact of CDR techniques and scenarios on the future evolution of the distribution se-floor carbonates. Alternatively (subject to successful installation on the lab's calculation server), the Earth System Model *i*Loveclim which already includes all the necessary carbon cycle related components, and which would furthermore allow to take into account the climate feedback, could also be used.

Requirements and prerequisites This thesis project requires programming skills. MBM-MEDUSA is written in Fortran 95 and needs to be adapted. Introductory training in Fortran 90/95 can be provided if required. Processing and analysis of the results has so far been done with IDL, but is progressively transiting to Python.

Basic knowledge of the carbon cycle would be useful, but is not indispensable, as this can be easily acquired from lecture notes, textbooks and scientific literature (rich collection available in the lab).

Infrastructure Developments on MBM-MEDUSA can be done on the students own computing devices (laptop, desktop PCs). If required or recommendable, a dedicated calculation server is available.

Stays abroad It should normally be possible to carry out this work completely in Liège.

Development of a coupled coral photosynthesis-respiration-calcification model

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Availability: by appointment

Thematics: climate, environment and oceanography

Description:

The World oceans’ coral reefs are important carbon sinks in the ocean and they contribute to regulate atmospheric CO_2 levels on time scales of a few centuries to tens of millennia.

Here, I propose to develop a model of coupled carbon alkalinity and oxygen fluxes as a result of photosynthesis, respiration and calcification by the different components of a coral. We are at first basing our developments on previously published models, such as those of Hohn and Merico (2012, DOI:10.5194/bg-9-4441-2012) or Nakamura et al. (2013, DOI:10.1007/s00338-013-1032-2).

Requirements and prerequisites This thesis project will obviously require programming skills. Once tested and validated, the model is meant to be included in ocean biogeochemical cycle models (multi-box models, EMICs or full 3D models). Accordingly, programming work would best to be done in Fortran 90 or better, as this is the source language of those models. I will provide introductory training in Fortran 90/95 if required. However, as early development stages of a new model generally require a lot of exploration tests, developments for this thesis can also be done in Python.

Furthermore, basic knowledge of biogeochemical cycles is recommended. Students must furthermore not be afraid of mathematics (differential equations, basic numerical methods, etc., at bachelors’ level).

Infrastructure Early stage developments can be done on the student’s own computing devices (laptop, desktop PCs). For computationally intensive work, a dedicated calculation server is available.

Stays abroad It should normally be possible to carry out this work completely in Liège.

Variable Redfield-Ratio Organic Matter

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<u>Availability</u>: by appointment

<u>Thematics</u>: climate, environment and oceanography

<u>Description</u>:

Most existing ocean biogeochemical models adopt a comparatively simple approach to represent the coupling of the nutrient (essentially nitrate and phosphate) and carbon cycles that arise from the production, transport and remineralization of organic matter: they adopt fixed C:N:P ratios, generally called Redfield ratios, to quantify the stoichiometry of organic matter. While this approach is justified to first order, there are regional deviations from these global average characteristics, and it seems that these ratios may also change in time, e. g., in response to the ongoing ocean acidification and global warming, or in relation to past climate changes, such as the Pleistocene glaciations. Hence, more and more biogeochemical models start to adopt variable organic matter stoichiometry to take into account this improved understanding of the coupled nutrient-carbon cycles.

Here, I propose to go one step further with these improvements, by also analysing the impact on the ocean-sediment exchange of nutrients, carbon and oxygen, using the the coupled ocean carbon cycle-sediment model MBM-MEDUSA (Munhoven, 2007, 2021): the ocean carbon cycle part will have to be extended to allow for variable C:N:P compositions of organic matter and a compatible MEDUSA configuration to be set up. Applications can address scientific questions of the past or the future evolution of the global carbon cycle.

Requirements and prerequisites This thesis project requires programming skills. MBM-MEDUSA is written in Fortran 95 and needs to be adapted. Introductory training in Fortran 90/95 can be provided if required. Processing and analysis of the results has so far been done with IDL, but is progressively transiting to Python.

Basic knowledge of biogeochemical cycles (carbon, phosphorus, nitrogen) would be useful, but is not indispensable, as this can be easily acquired from textbooks and scientific literature (rich collection available in the lab).

Infrastructure Usual developments and test simulations can normally be done on the student’s own computing devices (laptop, desktop PCs). For computationally demanding work, a dedicated calculation server is available.

Stays abroad It should normally be possible to carry out this work completely in Liège.

Investigating trajectories of marine litter/plastic in the Black Sea with a Lagrangian Simulator

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Availability : Contact by e-mail

Thematics : Oceanography

Description :

Lagrangian particle simulations are widely used in oceanographic research to estimate the pathways of particles transported by ocean currents. Their application in simulating trajectories of plastic litter and the formation of garbage patches is a hot topic in current oceanographic and marine environmental research. These simulations help understand the consequences of plastic pollution and can contribute to mitigating its environmental impacts. Our group at the University of Liege, the MAST, is interested in investigating the fate of marine litter and other particles in the Black Sea. We produce state-of-the-art physical-biogeochemical simulations of the Black Sea, which are ready to be used in Lagrangian particle simulations.

The student will learn to use the OceanParcels Lagrangian simulator, a computationally efficient tool that uses the Python programming language and that makes the addition of processes affecting the particle transport straightforward. Beyond advection processes by ocean currents, the student will incorporate diffusive processes, surface wave impacts, degradation processes, zooplankton grazing, etc., to analyze and differentiate their effects on plastic particle trajectories, the precise focus depends on the students interests (physics, biology…).

The project's outline and scientific questions will be collaboratively developed by the student under the guidance of supervisors. Throughout the project, the student will develop a fundamental understanding of Lagrangian simulators and the methodological considerations involved in their use (integrators, interpolation schemes …). Furthermore, the student will explore the diverse applications of Lagrangian simulators in oceanographic research and apply this knowledge to their simulation of particles in the Black Sea. By dispersing particles across various locations in the Black Sea, the student will for instance determine major concentration spots, how long and how far particles travel on average, the importance of different transport processes, and how the trajectories are related to the circulation in the Black Sea …

While the project focuses on marine litter/plastic, the insights gained are applicable to simulating various phenomena, including water masses, plankton, fish, suspended matter, pollutants, and more, thus holding significant interest for our entire group.

Specific methods, tools and material used: the OceanParcels Lagrangian simulator (https://oceanparcels.org/), a Python tool with a large user community and many available examples online; Ocean current data generated by our group with the NEMO model. If needed biogeochemical data from the BAMHBI model is ready to be used; Wave simulation data to simulate the impact of waves on surface transport

Using Lagrangian Simulations to analyse river plumes and the transport of suspended matter into the Black Sea

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Availability : Contact by e-mail

Thematics : Oceanography

Description :

Lagrangian particle simulations are widely used in oceanographic research to estimate the pathways of particles of any type (plastic, suspended matter, plankton, fish, oil spills …) transported by ocean currents and other processes. Our group at the University of Liege, the MAST, is interested in using this tool to investigate river plumes and to learn how they distribute sediments/suspended material into the Black Sea. We are producing state-of-the-art physical-biogeochemical simulations of the Black Sea, which are waiting to be used in Lagrangian particle simulations. The quantitative analysis of the river plumes will help to better understand physical and biogeochemical processes in the Black Sea, in particular the Black Sea North Western Shelf, which is very sensitive to the input by rivers.

The student will learn to use the OceanParcels Lagrangian simulator, a computationally efficient tool that uses the Python programming langage and that makes the addition of processes affecting the particle transport straightforward. Beyond advection processes by ocean currents, the student will incorporate sinking processes for different types of sediments, diffusive processes, surface wave impacts, degradation processes etc., to analyze and differentiate their effects on the evolution of the river plumes. Remote sensing satellite data will be used to evaluate the simulated river plumes.

The project's outline and scientific questions will be collaboratively developed by the student under the guidance of supervisors. Throughout the project, the student will develop a fundamental understanding of Lagrangian simulators and the methodological considerations involved in their use (integrators, interpolation schemes …). Furthermore, the student will explore various applications of Lagrangian simulators in oceanographic research and apply this knowledge to simulate and analyze river plumes in the Black Sea. While the project focuses on river plumes and suspended materials, the insights gained are applicable to simulating various phenomena, including water masses, plankton, fish, marine litter pollutants, and more, thus holding significant interest for our entire group.

Specific methods, tools and material used: the OceanParcels Lagrangian simulator (https://oceanparcels.org/), a Python tool with a large user community and many available examples online ; Ocean current data generated by our group with the NEMO model. If needed biogeochemical data from the BAMHBI model can also be used; Wave simulation data to simulate the impact of waves on surface transport; Satellite data for comparison to the simulated trajectories.

Skills the student will develop during this project: Formulating scientific questions and finding methods how to tackle them in the scientific literature; Expertise in the scientific analysis and visualization of geophysical data with a modern programming language (e.g in Python); Scientific writing; Working on a high performance computing cluster; Getting close to state of the art oceanographical research

Change detection from SAR imagery and Machine Learning techniques

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Availability: May, June

Thematics : Instrumentation and methods

Description

Change detection techniques based on imagery analysis have applications in many different areas including in the socio-ecological domain as the detection and the monitoring of human activities. The increasing number of Synthetic Aperture Radar (SAR) satellites observing the earth on a regular basis provides image time series that can be used to analyze changes. The manual analysis of SAR images to detect changes is a tedious task. The progress in Artificial Intelligence (AI) and in particular, in Machine Learning (ML) techniques, offers fast ways to perform change detection.

To develop an ML method for detecting changes from SAR images, a method for detecting changes from satellite image time series with ML techniques will be studied. It is based on a joint convolutional Auto-Encoder (AE) combining two convolutional AEs, AE1 and AE2, that are able, for each couple of images, to reconstruct both images from the other image of the couple by representing both images with a compact information, called features. In this context, an AE is composed of an "encoder" that generates the features and a "decoder" that reconstructs the image from its features. The reconstruction errors (REs) permit to detect the changes between the two images of all couples of consecutive images. Most change detection algorithms are supervised and need thus a large amount of labeled data. Finding labeled SAR data is difficult since it results from a costly and time-consuming task. In the proposed methodology, the detection technique does not require any labeled data, it is an unsupervised method. The amount of data needed for the learning process is generated by dividing images in patches. The model training is performed in two steps. The pre-training step consists of training the AEs making the joint AE, i.e. learning the features, on all images patches. The fine-tuning step consists of training two joint models AE1 and AE2 for every couple of images. In this context, we are looking for a motivated master student to explore the proposed ML method. This work would be considered for a specific target application, as part of an ongoing project with the purpose of detecting spatio-temporal environmental changes induced by mining activities in the Democratic Republic of Congo. Concerning the proposed ML change detection method, the student will be responsible for understanding its theoretical concepts, implementing and testing it, proposing and implementing a technique to assess it with respect to ground truth change maps and analyzing its performances. The outcomes of the master thesis are expected to contribute to the field of automatized detection of changes from SAR imagery.

Recommended skills/courses

SPAT0032-1: Remote sensing ; INFO8004-1: Advanced machine learning ; INFO8010-1: Deep learning; Programming (Python language)

Analysis of XRF spectra with Machine Learning techniques for sorting non-ferrous metal alloys

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Availability: May, June

Thematics : Instrumentation and methods

Description

Based on a technology developed by the ULiege department "Gemmes" for recycling non-ferrous metal scraps by families of alloys, the industry "Comet" developed an industrial line, MULTIPICK using 16 robots taking their sorting instructions from a bench of sensors (3D, hyper-spectral and X-ray Topography (XRT)). The metal sorted by MULTIPICK are mixtures of different alloy grades generally remelted for low-end applications. Sorting specific alloys permits thus to generate added economic and environmental value. The objective of a new project is thus the integration in the MULTIPICK line of Laser Induced Breakdown Spectroscopy (LIBS) and X-Ray Fluorescence (XRF) analytical sensors and data processing algorithms to sort specific alloys, in this case, aluminum and stainless-steel alloys. These algorithms will exploit the most recent developments in Artificial Intelligence (AI) and in particular in Machine Learning (ML) to process the data generated by all the sensors and provide identification of elements of the alloys of interest. The Electronics and the Signal Processing labs of the Centre Spatial de Liège (CSL) contribute to this project, the Electronics lab, by developing a new analytical XRF setup dedicated to stainless-steel and aluminum alloys, the Signal Processing lab by developing an ML method to process the XRF data, *i.e.* spectra.

To conceive this ML method, different ML models with Neural Network (NN) architectures proposed in the literature for the analysis of XRF spectra will be studied. The two first and simplest models have Fully-Connected Neural Network (FCNN) and Convolutional Neural Network (CNN) architectures that return from a single XRF spectra a vector of elements concentrations. The third model is based on the combination of an Auto-Encoder (AE) that represents the data in the form of compact information (a code) and a mapping module that transforms the code into a vector of concentrations of elements. The AE is composed of an "encoder" that generates the code and a "decoder" that synthesizes the data from this code. The proposed models have never been employed for the application field of the current project. In this context, the Signal Processing lab is looking for a motivated master student to explore one or more of the proposed ML models for the current project application. The student will be responsible for understanding the theoretical concepts of the chosen ML methods, implementing and testing them, proposing and implementing a technique to assess the methods with respect to a set of labeled XRF spectra, and analyzing their performances. The outcomes of the master thesis are expected to contribute to the field of automatized identification of metal alloys from XRF data.

Recommended skills/courses:

- INFO8004-1: Advanced machine learning
- INFO8010-1: Deep learning
- Programming (Python language)