Master Thesis Proposals

2018-2019

Space Sciences

Faculty of Sciences
Liège University

Astroparticles, Dark matter and Gravitational waves

Contact person : J.R. Cudell

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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 astropaticles

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.

A detailed analysis of the spectroscopic variability of the massive O supergiant HD152249

Contact person : Eric Gosset

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Tel : 04/366.97.54

Office: B5c, office 2-16, Groupe d'Astrophysique des Hautes Energies

Availability: At any time, but please send an Email in advance, in order to fix the date. Availability is very low from 4 June to 17 June.

Thematics : Astrophysics; Stellar physics; Observations; Spectroscopy; Pulsations versus Spots; Determination of the Physical Parameters.

Description:

The variability of massive O stars of the upper part of the Hertzsprung-Russell diagram is not yet fully understood. In particular, very few O supergiants have been studied. HD152249 is a star of spectral type O9I which is most probably single. However, the lines present in its spectrum exhibit weak profile variations that are easily detected in our high S/N observed spectra. A first observational campaign took place and confirms that the star exhibits line profile variations with a characteristic time scale lower than a day. This kind of variation could be associated to the presence of pulsations or to a spotted surface of the star or to other phenomena still to be discovered. Three other campaigns took place, one being particularly intensive. These data are not reduced yet, but should contain a wealth of new information.

The work will consist to start from the raw new observational data and to properly reduce them. The line profiles will then be inspected using various methods to investigate their probable variability and to further analyse and describe it. Once this analysis done, comparison of the line to line differential behaviour will be investigated in order to eliminate some explanations and to favour others. The physical parameters to be associated with the star will also be investigated. They will serve as a basis of an extensive discussion about the origin of the variability and of the compatibility of the possible origins with the theoretical models of this kind of star.

Study of the temporal distribution of X-ray flares from the supermassive black hole Sgr A*

Contact person : Enmanuelle Mossoux

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Tel : 04 366 96 84

Office : Institute of Astrophysics, Allée du 6 Août 19c, Bât B5c, room 2/9 (second floor, at the end of the corridor)

Availability : any day between 7:30 and 16:00 (please contact me to agree on a time slot)

Thematics : Astrophysics

Description :

Sgr A*, the closest supermassive black hole, is an extremely low luminosity black hole emitting flares in near-infrared, X-rays and radio. Since the beginning of the X-ray observations with modern telescopes (XMM-Newton, Chandra and Swift), there were about 2150 observations of Sgr A* leading to the detection of more than a hundred of flares.

The main goal of this master thesis is to determine if the change of flaring regime recently discovered considering the X-ray flares until October 2015 remains significant knowing the existence of flares newly detected since 2015. If the significance is proved, some constrains on the physical origin of this change of regime should be determined. This study may conduct to a scientific publication.

In practice, the student is asked to:
• get acquainted with Sgr A* and its flaring emission,
• reduce the new X-ray observations thanks to dedicated tools and extract the flaring light curve and spectra,
• study the distribution of the newly discovered flares,
• finally, compare the results to the literature and discuss the implications of the results.

This work can be extend to a study of characteristics of the X-ray flares from Sgr A*. Thanks to large number of X-ray flares, statistical studies can be performed to attempt to constrain some common characteristics. For example, evidences were found that the largest X-ray flares display an asymmetric profile with a rise phase much longer than the decay phase. Thanks to large number of small flares, we could be able to statistically analyze their profile and determine if they also follow an asymmetric profile. The spectra of all flares can also be simultaneously analyzed to determine if the spectral characteristics are varying between the flares, if they are somewhat related to the energy of the flares,...

Recommended course: SPAT0009-1 *High-energy astrophysics* (Pr G. Rauw).

Line profile variability in two peculiar massive stars

Contact person: Gregor Rauw & Yaël Nazé

e-mail: rauw@astro.ulg.ac.be

Tel : 04/3669740

Office: B5c, 2/2

Availability: Interested students should contact the contact person by e-mail to find the best time for an appointment.

Topic: Astrophysics

Description:

Some massive O-type stars display variations of their spectral lines that hint either at (non-radial) pulsations at their surface or structures inside their stellar winds. Studying these phenomena opens up 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 stellar winds bear information about the dynamics of stellar winds and the possible impact of magnetic fields. Observationally studying these phenomena requires long series of high-quality spectroscopic observations. Over recent years, our team has collected such data for several peculiar O-type stars. And we propose here an in-depth study of two objects.

The student is asked to

- get acquainted with the subject of spectral line profile variability in massive stars, and with the current knowledge of the variability of the two targets,
- reduce and normalize the spectroscopic observations that have been collected to study the variability of both targets,
- 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 both stars in the literature and discuss the implications of the results.

Having attended the classes on “Variable Stars” (SPAT0007) is certainly helpful.

Investigating the multiplicity of a massive star

Contact person: Gregor Rauw

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Tel : 04/3669740

Office: B5c, 2/2

Availability: Interested students should contact the contact person by e-mail to find the best time for an appointment.

Topic: Astrophysics

Description:

This project is to study the spectra of a bright multiple stellar system dominated by a star of spectral type O9. The lines of this latter object describe an SB1 orbital motion on a period of about 155 days. Moreover, the system is believed to host an eclipsing binary with a very short period of 1.282 days. The link between the O9 star and the eclipsing binary is not clear. Actually, so far, no spectroscopic signature of the eclipsing binary has been identified. Based on a large set of spectroscopic data obtained with a spectral resolving power near 28 000, we propose to revisit the multiplicity of this system to look for the spectroscopic signatures of the companion of the O9 star, and of the stars that make up the eclipsing binary.

The student is asked to

- get acquainted with the subject of spectroscopic and eclipsing binaries, and with the existing literature on the target,
- normalize the spectroscopic observations, measure the radial velocities of the O9 star, and search for signatures of its companion, and/or of the short-period eclipsing binary,
- apply an existing code to disentangle the spectra of the O9 star and any other component that can be identified in the spectra,
- analyse the existing light curve of the eclipsing binary and derive constraints on the properties of the stars that make up this system,
- and finally, summarize the current best view of this multiple system and discuss the implications of the results.

Having attended the classes on “Variable Stars” (SPAT0007) is certainly helpful.

Diagnosing and calibrating the multi-century sunspot number series

Contact person : Frédéric Clette

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Tel : 02/373.02.33

Office: Observatoire Royal de Belgique, Physique solaire, 3 avenue Circulaire, 1180 Bruxelles

Availability: Mon 21 may (10-12h), Tue 6 june (10-12h), Tue 19 june 2017 (10-12h)

Thematics : Solar physics, solar cycle, sunspots, data mining, time series and error analysis

Description:

Visual sunspot observations are at the base of the single longest scientific record of solar activity, spanning four centuries. The primary reference index, called sunspot number, was recently submitted to a full revision and re-calibration. A new significantly modified series was released in July 2015, shedding new light on our understanding on the long-term variations and instabilities of the 11-year solar cycle. However, uncertainties remain and errors in past historical data need to be established using the present state-of-the-art statistical and data mining techniques. A good overview of the ongoing effort was the theme of a recent special issue of the Solar Physics journal (Vol 291, N° 9-10: http://link.springer.com/journal/11207/291/9/page/1). This revival of long-term studies aims at addressing our current inability to predict the future evolution of the solar cycle, a key quest in solar physics, at constraining the latest physical models of the solar dynamo, and at improving our understanding of the solar influence on Earth climate change.

In the framework of this thesis, we will exploit the full database of raw sunspot counts maintained by the World Data Center SILSO (sidc.be/silso), which contains more than 500.000 observations spanning several centuries, in order to derive a better understanding of the scale differences between past observers, by exploiting modern data from the current worldwide SILSO observing network. Indeed, a key issue when building such a long-term record is to bring all observations to the same normalization scale, by diagnosing and compensating various inhomogeneity factors (instrumentation, observing practices, etc.). The abundance of modern data (280 stations) allows to implement statistical techniques to derive the noise properties of past data (often loosely documented) and advanced data mining techniques (multi-variate analysis) to address e.g. data gaps in sparse series or to identify “families” of observers sharing common characteristics. This analysis will help shedding light on remaining discrepancies in past sunspot observations (direct indicator of solar activity level) and also between sunspot data and parallel solar and geomagnetic records.

For this thesis, the solar team at the ROB will provide guidance based on years of world-recognized expertise. The World Data Center SILSO, hosted at the ROB, is indeed at the core of the current ongoing research in this field. Although this is a time-limited master thesis, this training period may thus directly lead to useful results supporting current ongoing research, and it can perfectly be expanded later on as a full PhD research project. Although our team is based in Brussels, a significant part of the work can be carried out remotely, as the base data are accessible or storable off-site. However, for the good progress of the daily work, we assume that the student would spend one day in Brussels at least twice per month to interact directly with the promoter at the ROB. The main pre-requisites are a good base knowledge of time series and statistical error analysis, and an interest in astronomical data processing and data mining techniques, and in long-term solar activity.

Modeling extreme horizontal branch stars by asteroseismology

Contact person: Valérie Van Grootel

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Office: B5c, room 1/13

Availability: Early May at the office; after that by email.

Thematics: Astrophysics: stellar physics, asteroseismology

Description:

This master thesis concerns asteroseismology, the study of stellar oscillations in order to tightly constrain the physics inside stars and hence, to refine the models of the structure and the evolution of stars. The proposed project spans from observational data reduction and analysis, to theoretical modeling by comparison between observed and theoretical oscillation properties of various stellar models.

The stars studied in this master project are extreme horizontal branch stars, also known as subdwarf B (sdB) stars. They represent an advanced stage of stellar evolution, after the main sequence where the stars spend most of their lives and after the first red giant phase. These hot (T_{eff}=20,000-40,000 K) and compact (log g=5.2-6.2) objects burn helium in their cores into carbon and oxygen and are surrounded by an extremely thin H-rich envelope. Understanding the formation of sdB stars is one of last big mysteries of stellar evolution.

The proposed master thesis concerns the asteroseismic modeling of PG 1336-018, a pulsating sdB star member of an eclipsing binary that has been observed with the 1.6-m Mount Bigelow telescope from January to June 2017. Because the PG 1336-018 sdB star is member of an eclipsing binary, its mass and radius are accurately and precisely known from orbital modeling, providing the most stringent test for sdB models and asteroseismology of evolved stars in general. First step will consist in cleaning and reducing observational data, and second step in extracting the frequencies of stellar oscillations. The third step is the asteroseismic modeling itself, by quantitatively comparing the computed oscillation periods for large sets of stellar models to the observed periods. By optimizing this comparison (through genetic algorithms that have been developed for this purpose) to find the best-fitting model to the observations, the seismic modeling will yield the global parameters (e.g. stellar mass and radius) and internal structure and composition (e.g. envelope layering, core composition) of the star. The final objective will be to model the rotation period and internal rotation profile of the sdB star, by interpreting frequency multiplets associated to stellar rotation. This is particularly interesting for stars in close binaries such as PG 1336-018, which experience strong tidal interaction with its companion star. This is thought to lead to full spin-orbit synchronism (equality of orbital and rotation periods throughout the star). Determining internal rotation profile will provide stringent constraints for poorly constrained tidal friction theories.

Recommended courses: SPAT0005-1 *Stellar Stability and asteroseismology,* SPAT0045-1 *Stellar structure and evolution II* (Pr. M.A. Dupret)

Simulations of photometric performance of a CubeSat

Contact person : Valérie Van Grootel & Sébastien Salmon

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Tel : +32 4366 9730/9765

Office: B5c, room 1/13 or 1/14

Availability: Anytime in May or June except 16-30 May (S. Salmon). Early May or by email (V. Van Grootel)

Thematics : Instrumentation and methods

Description:

CubeSats are a class of standardized nanosatellites (spacecrafts that weigh 1-10 kg) by unit "U" of 10x10x11 cm^3. They are an expanding space activity, with several hundreds of CubeSats forecasted for a launch in the coming years, including for scientific purposes. In particular, thanks to huge technical progress in satellite pointing stability and attitude control, high-precision photometry for astrophysics is now achievable.

NANESSE[1] is a Liege-led project of a 3U CubeSat dedicated to high-precision photometry of Alpha Centauri, our closest stellar neighbour. Alpha Cen is composed of two stars similar to the Sun, and a more distant, but thought to be gravitationally bound, faint red dwarf, Proxima.

NANESSE has 3 scientific purposes: (1) to measure stellar oscillations of Alpha Cen A (1-10 ppm amplitudes); (2) to monitor the stellar activity of both components (~100 ppm amplitudes); and (3) to search for Earth-sized transiting planets (~60-100 ppm amplitudes) around Alpha Cen A, B, or both. The most interesting low-Earth orbits to ensure optimal visibility of Alpha Cen are sun-synchronous dawn/dusk (6h/18h) orbits, where a satellite rides the terminator between day and night.

The goal of this master thesis project is to characterize the photometric performance of a 3U CubeSat in a dusk/dawn orbit like NANESSE. Several solutions for the design of the payload and the platform will be quantified and tested for their photometric performance. This will allow us to dimension the optical design in order to meet the scientific objectives. The performance simulator for the CHEOPS space mission (http://sci.esa.int/cheops/), for the preparation of which the promoters of this master thesis are implied, will be used as the tool to carry out the simulations.

Recommended courses: SPAT0035-1 *Space Exploration* (G. Rauw), AERO0018-3 *Space experiment development* (J. Loicq)

1 Nanosatellite for Asteroseismology and activity of the NEarest Stellar System with Exoplanets

Revisiting the instability strips of sdB stars

Contact person : Valérie Van Grootel & Marc-Antoine Dupret

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Office: B5c, room 1/13 or 1/12

Availability: V. Van Grootel : early May, or by email ; M-A Dupret: anytime in May or June

Thematics : Astrophysics: stellar physics, asteroseismology

Description:

The stars studied in this master project are extreme horizontal branch stars, also known as subdwarf B (sdB) stars. They represent an advanced stage of stellar evolution, after the main sequence where the stars spend most of their lives and after the first red giant phase. These hot (T_{eff}=20,000-40,000 K) and compact (log g=5.2-6.2) objects burn helium in their cores into carbon and oxygen and are surrounded by an extremely thin H-rich envelope. Understanding the formation of sdB stars is one of last big mysteries of stellar evolution. Some sdB stars present pulsations, which open the possibility to apply asteroseismology (the study of stellar pulsations) to model these stars.

The proposed master thesis concerns the instability strip of sdB stars: we aim to determine when (i.e. at which masses, effective temperature and surface gravity) these stars present excited pulsation modes and when they are not predicted to pulsate. Three groups of sdB pulsators are known: the short-period (80-500 sec) sdB pulsators with temperatures T_{eff} around 34,000K which were the first to be discovered; the long-period (1-3h) sdB pulsators with cooler T_{eff} around 28,000 K and lower surface gravities; and finally very hot (50,000-60,000 K) and very compact post-sdB pulsators with very short periods (less than one minute), recently found. Our classical models of sdB stars correctly predict and reproduce the properties of the pulsations of the first group (the short-period pulsators), but not at all those of the second (long-period) and third (very hot) group. The culprit is identified since a couple of years: the absence of Ni in our sdB models. Unfortunately, no trustable opacity tables for Ni were available to us until very recently. This is now the case, and new sdB models including Ni have now been built.

The aim of this Master thesis is to revisit the instability strips of the three groups of sdB pulsators with these new sdB models. The goal is to determine if we can still correctly reproduce the pulsation properties of the first group of sdB pulsators, and if we can better reproduce the observed instability strips of the second and the third groups with these new models. The non-adiabatic MAD pulsation code (developed by Pr. Marc-Antoine Dupret) will be used to pulsate the sdB models. In particular, the MAD code includes various prescriptions for the interaction between pulsations and convection, a potentially important effect to account for pulsations in sdB stars, but that has never been tested.

Recommended courses: SPAT0005-1 *Stellar Stability and asteroseismology,* SPAT0045-1 *Stellar structure and evolution II* (Pr. M.A. Dupret)

Convection in pulsating white dwarfs

Contact person : Marc-Antoine Dupret & Valérie Van Grootel

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Tel : +32 4366 9732/9730

Office: B5c, room 1/12 or 1/13

Availability: M-A Dupret: anytime in May or June; V. Van Grootel: early May or by email

Thematics : Astrophysics: stellar physics, asteroseismology

Description:

This master thesis concerns white dwarfs, the final stage of the evolution for the vast majority (97%) of stars in the Universe. White dwarfs exhibit several classes of pulsations, which allow us to apply the tools of asteroseismology in order to tightly constrain the physics inside these stars and hence, to refine the models of their structure and their evolution. It also focuses on the most important problem in current modelling of stellar oscillations: their coupling with convection.

The objective of this master thesis is to improve our understanding of the pulsation properties in white dwarfs. In these stars, the mechanism that drives pulsations is concentrated at the base of the upper (envelope+atmosphere) convective layers. Two key ingredients are therefore required to accurately model white dwarfs and their pulsations: interaction between pulsations and convection, and accurate modelling of the upper layers. The first ingredient is now taken into account thanks to the non-adiabatic MAD pulsation code (developed by Pr. Marc-Antoine Dupret) and fully implemented in our (1D) standard models of white dwarfs. For the accurate modelling of upper layers, full 3D hydrodynamical simulations are now available (see the recent work of P.-E. Tremblay, one of our collaborators), and their results has now to be exploited.

In this master thesis, the pulsation properties of white dwarfs including an accurate modelling of the surface convection will be investigated for the first time. So-called patched models of white dwarfs - 1D models with upper layers deduced from 3D simulations – will be analysed. The first step will be to compute adiabatic pulsations (this should be an excellent approximation for pulsations periods, since they are mainly determined in adiabatic regions). By comparing these periods with those obtained from standard 1D models, the first objective is to assess for the first time the impact of the current approximate modeling of the superficial layers, the so-called surface effects. The second step is to compute non-adiabatic pulsations of these patched models, by using the MAD code developed by M-A Dupret. The objective is to assess the importance of an accurate upper layers modeling on the range of excited pulsations and on the instability strips of pulsating white dwarfs. The main problem at this level is Time-Dependent Convection (TDC). A new TDC model has been very recently developed by M-A Dupret. The student will apply it to patched models of white dwarfs for the first time. This will constitute a first look to this major problem achievable within this master project, but a full investigation of this problem would constitute an excellent topic for a subsequent PhD thesis, with the goal of solving the discrepancies currently encountered with the observed instability strips of pulsating white dwarfs and significantly improving the accuracy of the modeling of oscillations in the near-surface layers of solar-type stars.

Recommended course: SPAT0005-1 *Stellar Stability and asteroseismology* (Pr. M.A. Dupret)

Probing rotation with Rossby waves in γ Doradus stars

Contact person : Sébastien Salmon & Marc-Antoine Dupret

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

Availability: S. Salmon, from 1st to 15th May, anytime in June / M.-A. Dupret, anytime in May or June

Thematics : Astrophysics: stellar physics, asteroseismology

Description:

The γ Doradus stars are main-sequence A- and F-type stars presenting high-order gravity modes of pulsation. 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 runs actually revealed rich and complex stellar pulsation spectra in hundreds of γ Dor stars. Since a large fraction of these stars are moderate to fast rotators, the analysis of their pulsations has revealed a huge potential for characterising their internal rotation profile and thus internal transport processes of chemical species and angular momentum. In particular, very recent studies reported convincing evidence of the detection of Rossby waves. These gravito-inertial waves only appear with rotation since Coriolis force acts as part of their restoring force. Theoretical aspects of Rossby waves have already been studied in other types of stars. But the potential of these waves to characterise rotation and the regions in which they propagate in γ Dor stars is mainly unexplored hitherto.

Within the ASTA team, we are developing for many years numerical tools allowing us to independently model stars from their structure to the computation of their pulsations, including the energetical (non-adiabatic) aspects. With help of these unique tools, the student will compute and study non-adiabatically the Rossby modes on a grid of stellar models representative of γ Dor stars. He/she will derive the expected domain of instability of these modes, depending on the fundamental properties of the stars and their rotation. He/she will also focus on the potential of these modes to constrain the stellar rotation, including comparison with claimed Rossby wave detections in Kepler stars. Depending on the progress of the student, other aspects such as mode visibility computations can be envisioned in this subject.

Recommended courses:

SPAT0005 *Stellar Stability and asteroseismology* (Pr. M.-A. Dupret)

SPAT0044-45 *Stellar structure and evolution I and II* (Pr. M.-A. Dupret)

Determination of physical parameters of supernova remnants through radio observations

Contact person : Michaël De Becker

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Tel : +32 4366 9717

Office: B5c, room 2/8

Availability: Please contact me by e-mail

Thematics : Astrophysics

Description:

The evolution of the most massive stars leads to the core-collapse supernova event. The stellar core tuns into a neutron star or a black hole, while the outer layers of the star are ejected at high speeds. The residual astronomical environment is called a supernova remnant.

The shocks produced by shell-type supernova remnants with the surrounding interstellar material are able to accelerate particles up to relativistic velocities. As a result, radiation processes involving notably relativistic electrons are active. In particular, synchrotron radiation is observed in such systems over several orders of magnitude in photon energy. Measurements of the radio emission (size of the emitting region on images, flux densities, spectral indices...) allow to make an assessment of physical parameters, such as the magnetic field strength and the normalization parameter of the relativistic electrons population, provided relevant assumptions are made, notably about energetic partition (in particular between magnetic field and relativistic particles, and among relativistic particles).

Content of this master thesis:

- introduction to shock physics, to non-thermal physics, and to radiative processes relevant for supernova remnants, based on the adequate bibliography (in complementarity with the course on Radio Astrophysics),

- hands-on activities on real Very Large Array data using the CASA software (the new standard for data processing in radio astronomy),

- the use of published information about supernova remnants to investigate physical parameters on a sample of objects,

- discussion on the incidence of some assumptions made in the description of the underlying physics on the determination of some important physical parameters.

Depending on preferences expressed by the student, the weight of the different parts of the master thesis can be adapted. Suggestions by the interested student are of course welcome and could be considered depending on their feasibility.

Recommended course: SPAT0069-1 Radio astrophysics (M. De Becker)

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

Contact person: Emmanuël Jehin (ULiège)

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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 telescope 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 an article.

The work will be done in the comet group of the OrCa Service (+1) and the TRAPPIST team
http://www.trappist.uliege.be/cms/c_3300885/en/trappist-portail

Study of fireballs with BRAMS and FRIPON

Contact person : Emmanuel Jehin (ULiège), Hervé Lamy (IASB)

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Office: B5c 1/9

Availability: E. Jehin will be available most afternoons in May and June.

Thematics : Planetology and planetary systems

Description:

Every day, the Earth's atmosphere is hit by tiny dust particles collectively called meteoroids with a small part of them bigger enough (size ~ 1 cm) to produce a visible phenomenon called meteor (or shooting star). Fireballs are very bright meteors due to much larger objects entering the atmosphere. These objects penetrate much deeper in the atmosphere and might not be fully ablated leaving a strongly slowed down small part which falls down freely to the ground as a meteorite.

Meteors can be observed from the ground either with optical or radio techniques. With the latter, a radio wave is sent from a transmitter on the ground and is reflected on the ionized trail created by the meteoroid along its path when hitting atoms and molecules of the upper atmosphere. For fireballs, a reflection can also be obtained on the ionized region in front of the meteoroid.

In this master thesis, we propose to study fireballs observed above Belgium with both optical and radio techniques. For optical observations we will use data from FRIPON (Fireball Recovery and InterPlanetary Observation Network, www.fripon.org) which is a French network of all-sky cameras separated by typically 100 km. A detection of a fireball by several cameras allows a reconstruction of the fireball trajectory and speed. FRIPON has lately been extended to other countries including Belgium. One camera is on the roof of BISA in Uccle and is running since 2016. Another one will be installed at ULiège in summer 2018. For radio observations we will use data from the BRAMS (Belgian RAdio Meteor Stations, brams.aeronomie.be) which is a network run by IASB and made of a dedicated transmitter located in Dourbes (South-East of Belgium) and about 25 receiving stations located all over the Belgian territory, one of them being at the University of Liège and running for a few years.

The following tasks will at least be carried out by the candidate:

- Understand how both BRAMS and FRIPON experiments works and what data are produced
- Study of overdense trail meteor echoes observed by the BRAMS network : timing, power variation, relation to mass?
- Study of head echoes observed by BRAMS : determination of the speed of the meteoroid from multi-station observations, comparison with FRIPON estimate of speed.
- Comparison of trajectories of fireballs retrieved from BRAMS and FRIPON data

This work will be done in collaboration with the BRAMS team (PI : Hervé Lamy) working at BISA (Belgian Institute for Space Aeronomy) and with the FRIPON team (PI : François Colas) working at Observatoire de Paris.

Imaging habitable exoplanets

Contact person : Denis Defrère, Olivier Absil

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Office: B5c 2/4

Availability: any day (please contact us to agree on a time slot)

Thematics : Planetology and planetary systems, image processing

Description:

The detection and characterization of exoplanets is one of the major science cases of modern astronomy. In particular, the University of Liège is currently involved in two major projects to search for habitable exoplanets around nearby sun-like stars. The first project, called NEAR, will focus on the alpha Centauri system and start its observing campaign in 2019 using the Very Large Telescope installed in Chile. The second project, called METIS, is an instrument for the future Extremely Large Telescope (ELT) and will search for habitable exoplanets around a sample of nearby Sun-like stars (2025+). One of the major issues to reach the sensitivity required to detect habitable exoplanets is the overwhelming flux from atmosphere, which is at least one million times brighter than an Earth-like exoplanet located around our nearest stellar neighbor. In order to enable such a detection, the thermal background from the atmosphere has to be carefully removed using dedicated image processing techniques.

Under the supervision of the department of Astrophysics, Geophysics, and Oceanography (AGO), the goal of the master thesis will be to test and compare different innovative background subtraction techniques. These techniques will be tested on existing data sets obtained with similar instruments such as ESO's VLT/VISIR installed in Chile and NASA's LBTI/NOMIC installed in Arizona. The optimized background subtraction technique will then be applied to scientific data of a sample of ~30 stars in order to look for the signs of mature planetary systems. The results of the master thesis will be timely with the upcoming NEAR project and are expected to have a high impact on the scientific preparation of METIS.

Recommended master courses :

- SPAT0063-1 : Introduction to exoplanetology
- SPAT0067-1 : Atmospheric and adaptive optics
- SPAT0056-1 : Planetary and exoplanetary atmospheres

Analysis of TRAPPIST observations of Io's sodium jets

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Office: B5c 0/2, B5c 1/9

Availability: B. Bonfond will be available most afternoons in May and June.

Thematics : Planetology and planetary systems

Description:

For this Master Thesis, we propose to use freshly acquired TRAPPIST images of Io with a sodium filter to study jet emission and unveil some of the mysteries of the Jovian system. Jupiter is a very complex planet, differing in many ways from the Earth. For example, the magnetosphere is dominated by particles originating from Io. With more than 400 volcanoes, this moon is the most active body of the solar system. Contrary to the Earth, the volcanism is mainly fuelled by the powerful tides agitating Io's mantle. Either directly or indirectly, the material spewed from these volcanoes form a tenuous and patchy atmosphere. As it escapes from the atmosphere, this material, essentially made of sulphur and oxygen, first gets ionised and accumulates in the form of a plasma torus along the orbit of Io before it migrates radially. It is the complex dynamics of this outward moving plasma that drives Jupiter's powerful aurorae. However, many links of the chain connecting the volcanoes at Io to the magnetosphere through Io's atmosphere and plasma torus are still poorly understood.

TRAPPIST (TRAnsiting Planets and PlanetesImals Small Telescope) is a project devoted to the detection and characterization of planets located outside our solar system and to the study of comets and other small bodies in our solar system. It consists of two 60cm robotic telescopes located at the ESO La Silla Observatory in Chile and at Oukaïmden Observatory in Marocco. Contrary to oxygen and sulphur, sodium is a trace component, but its powerful line in the visible spectrum make it an ideal tracker of the connection between Io's atmosphere with the Io torus. In the frame of this Master thesis project, the student will calibrate, process and interpret the dataset of images acquired in 2016 with TRAPPIST South and during 2018 with TRAPPIST North. He or she will be supervised by both Emmanuel Jehin and Bertrand Bonfond.

Jupiter’s auroral bridge

Contact person : Denis Grodent

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Office: B5c 0/17

Availability: Please, contact me by email to set a meeting time

Thematics : Planetology and planetary systems; Instrumentation and methods

Description:

Jupiter’s bright ultraviolet aurorae consist of several components, each of which is presumably associated with a specific location in the magnetosphere and a particular generation process. The first step in the identification of such a component is the determination of its occurrence rate in the dataset. We are then interested with the morphological characteristics of this auroral feature, from which we can determine the magnetospheric region from where it originates. The ultimate step is the interpretation of this auroral phenomenon.

The present Master thesis consists in analysing the current set of observations that we obtained, and are still obtaining, with the Hubble Space Telescope. This dataset is fully accessible on our data servers and contains several thousands of images that have been pre-processed in such a way that they can be handled by semi-automatic procedures. Some programming (IDL) will be necessary to analyze the data. Jupiter’s auroral bridge is one such feature. Its (unofficial) name points to the fact that it appears to link two other auroral components, the main emission and the active region, that, so far, are not expected to share any physical connection. The goal is to isolate the auroral feature and to determine its principal characteristics.

More information on Jupiter’s UV aurora may be obtained here (previous Master thesis on Jupiter’s aurora): http://hdl.handle.net/2268/154269

Preview movies and additional information about the Jupiter-Hubble-Juno campaign are available here: http://www.lpap.uliege.be/cms/c_3478756/en/lpap-hst-campaign

The Dark region in Jupiter's aurorae

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Office: B5c 0/2

Availability: I will be available in my office most afternoons in May and June.

Thematics : Planetology and planetary systems

Description:

The proposed project consists in using image processing tools to analyse the aurorae at Jupiter. The brightest aurorae of the solar system can be found at this planet. Caused by the impact of charged particles into the planetary neutral atmosphere, these light emissions synthesize the processes taking place in the whole magnetosphere. Contrary to the Earth, these aurorae are powered by the planetary rotation and fuelled by the particles ejected from the volcanic moon Io. The Jovian aurorae are thus a paradigm for a completely different kind of aurorae than the solar-wind-driven ones at Earth.

Jupiter and its aurorae are currently under great scrutiny, as the Juno spacecraft orbits the planet since July 2016. Among its instruments is a UV imaging spectrograph, named Juno-UVS, dedicated at giving global and close-up spectrally resolved pictures of the atomic and molecular hydrogen in the 60-200 nm wavelength range. In order to complement these observations and get the most of this unique opportunity, many Earth-based observatories, such as the Hubble Space Telescope, are also pointed towards the Giant Planet.

Actually, the purpose of this Master Thesis project is not to look at the aurorae, but to look for the regions devoid of them. Indeed, in the region located inside the main auroral oval lies a so-called "Dark-region", supposedly related to return currents accelerating electrons away from Jupiter rather than towards its poles. The student will create an automated method to identify and measure the characteristics (size, location, brightness, etc.) of this region on Hubble Space Telescope and Juno-UVS auroral observations.

Saturn’s outer auroral emission

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Availability: Contact me by e-mail

Thematics : Auroral emission of Saturn – processes of the inner magnetosphere

Description:

This study is based on the analyses of auroral data obtained from the Ultraviolet Imaging Spectrograph (UVIS) instrument onboard Cassini. Cassini was in orbit around Saturn from 2004 to 2017. Cassini entered its ‘Grand Finale’ phase in November 2016, during which it approached Saturn and captured unprecedented views of Saturn’s aurora until the end of the mission on 15th of September 2017.

The focus of this study is to statistically describe the outer auroral emission in terms of local time, brightness and magnetically mapped location on the equatorial plane. In a second step the statistical properties will be used to relate the auroral emission to processes taking place in the inner magnetosphere of Saturn.

Analysis of the generation of cloud bands on Jupiter or Saturn

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Office: B5a 2/5

Availability: Preferentially monday's afternoon.

Thematics : Planetology, Geophysical Fluid Dynamics

Description:

Cloud bands are visible both on Jupiter and Saturn with a strong zonal flow direction alternating from the equator to the poles. The proposed works aims at analysing the dynamics leading to such behaviours, focussing on one of the two planets.

The student will start with an analysis of the different explanations provided up to now, including their hypothesis on thermodynamics and geometrical constraints (barotropic or baroclinic modes, vertical extensions and dynamics, small-scale turbulence effects etc). Based on the current knowledge of Jupiter's or Saturn's atmosphere, a model providing a good compromise between realism and simplicity will be chosen for further investigation. In particular, the idealized model will then be used to simulate how coherent structures as a big vortex or the bands can emerge and under which conditions involving geostrophic turbulence and planetary waves. Testing hypothesis will typically include activating or deactivating certain processes during the simulations. The focus of the work is thus the understanding of the underlying dynamics and less the best reproduction of observations.

If the analysis turns out to be strongly dependant on a poorly known parameter, the study could actually be turned into an inverse problem. In that case, using actual observations on the band distributions, the parameter could be calibrated and the thesis provide an indirect estimate for it.

The work will rely on a good understanding and analysis of fundamental geophysical fluid dynamics and the use of numerical models.

Effects of the atmosphere of Mars on Lenght-of-day variations

Contact person: Véronique Dehant, co-promoter: Emmanuelle Javaux

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Tel: 02 373 0266

Availability: [take a rendezvous per email]

Thematics: [Planetology and planetary systems]

Description:

The rotations of the Earth and of Mars are influenced by the existence of an atmosphere (and for the Earth, to a minor extend by the existence of oceans). To explain length-of-day variations, we must consider the angular transfer between the solid planet and the atmosphere. For Mars in particular, due to the seasonal sublimation and condensation of CO_2 in the ice caps, there is a large change in the LOD. About one fourth of the atmosphere is participating in this process. It produces a change with respect to the line-of-sight from the Earth of about 15 meters for a lander near the equator. In order to compute this, it is necessary to consider the global circulation in the atmosphere and compute the angular momentum. This is computed by running General Circulation Models (GCMs) that are available, built on atmospheric observations. The codes can be run by the student and the angular momentum can be computed for different years and different scenarios like global storm or not. It was already done for GCM available in 2002 (Van den Acker E., Van Hoolst T., de Viron O., Defraigne P., Dehant V., Forget F., and Hourdin F., 2002, “Influence of the winds and of the CO_2 mass exchange between the atmosphere and the polar ice caps on Mars' orientation parameters.”, J. Geophys. Res. (Planets), 107(E7), pp. 9-1, CiteID 5055, DOI: 10.1029/2000JE001539). But GCMs have been improved since then. It is important to re-compute this as we will get in a few months the data from the RISE experiment (Rotation and Interior Structure Experiment) within the InSight ((Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission landing on 26 November 2018.

Investigation of Mars surface H_20 and CO_2 ice and atmosphere-surface interactions with Trace Gas Orbiter

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Thematics: Planetology and planetary systems

Description:

Understanding ongoing processes related to the temporal and spatial variations of surface H_20 and CO_2 ices, presence of liquid water, and exchange of trace species between the subsurface and the atmosphere are among the key open scientific problems, challenging our current understanding of the fundamental behavior of the Martian climate. Subsurface processes may produce emission of volatiles as well as trace gases into the atmosphere. The destabilization of subsurface ice and/or clathrates has been proposed as a mechanism for the formation of apparently present-day active fluid features on the surface and as a source for atmospheric trace gases such as methane. There is also recent evidence that liquid water may flow intermittently on present-day Mars probably due to the presence of perchlorate and other salts as sources of ions that can lower the freezing point of aqueous solutions. ESA's Trace Gas Orbiter (TGO, see figure) which has recently entered in Mars orbit will monitor the spatial and temporal variations of Mars atmosphere with emphasis on volatiles and trace gases.

In this Master thesis study, Mars surface atmosphere interactions will be carried out based on NOMAD (Nadir and Occultation for MArs Discovery) spectral observations in collaboration with scientists from Royal Observatory of Belgium and Royal Belgian Institute for Space Aeronomy (PI- Institute of the NOMAD). NOMAD is a spectrometer suite onboard TGO that can measure the spectrum of sunlight across a wide range of wavelengths (infrared, ultraviolet and visible). This broad coverage of the instrument enables the detection of the components of the Martian atmosphere and surface, even in low concentrations.

During the study, spectral data will be studied in terms of composition of surface properties. Bidirectional reflectance and the related photometric parameters will be considered in order to characterize the Martian surface. Models will be fitted to the observed data, which may include a spatial mixture of regolith, H_20, CO_2 ices, brines (mixture of water and salts) and clathrates. Since the NOMAD science phase is foreseen to start in early spring 2018, the spectra from previous Mars missions (Fourier spectrometer (PFS) and OMEGA onboard Mars Express and Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) onboard the Mars Reconnaissance Orbiter) will be first used to validate the proposed approach before applying to newly acquired NOMAD data set. Moreover, the proposed study will help to characterize also the variations in angular momentum due to the redistribution of masses in global scale, such as the migration of ice from the polar caps to the atmosphere and temporal and spatial variations of surface ices. These phenomena are critical for the forthcoming radio science experiments RISE onboard 2018 InSight mission (see figure on the right) and LaRa (Lander radio-science experiment, PI institute is ROB) onboard ExoMars 2020.

This work can lead to a publication and to a continuation into a PhD thesis.

Study of water on Mars in the frame of ExoMars mission

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Availability: [take a rendezvous per email]

Thematics: Planetology and planetary systems

Description:

Recent observations of HiRISE, the camera onboard Mars Reconnaissance Orbiter (MRO), have provided strong evidence on the intermittent presence of salt-saturated liquid water on the Martian surface. Recurring slope lineae (RSL), narrow and dark flow features appear and grow on the slopes of Mars during warm seasons and disappear during cold seasons. The detection by MRO of hydrated salts where RSL are present suggests that these flows would consist of brines made of magnesium perchlorate, magnesium chlorate and sodium perchlorate. Current temperature and pressure conditions at the surface of Mars do not allow pure liquid water to remain stable but the presence of salt can lower the freezing point of water up to 70K. If RSL are indeed formed by brines, it provides new clues to understand the nature of the present-day Martian water cycle.

In this Master thesis, the presence of salt-saturated liquid water at the surface and in the Martian subsurface will be investigated. A subsurface thermal model including a detailed implementation of slope effects will be developed and used to obtain the temperatures at the surface and in the subsurface in combination with atmospheric models and available observations from Mars orbit (ExoMars Trace Gas Orbiter) and surface (Mars Science Laboratory, Phoenix lander). The model will be applied locally to study liquid water stability according to the ground thermal properties and the presence of different salts. The study will help to better understand the brines and in addition to prepare the forthcoming ExoMars rover and surface platform investigations.

This work can lead to a scientific publication and possibly to a doctoral thesis.

Mars rotation from SBI (Same Beam Interferometry) radio science measurements

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Availability: [take a rendezvous per email]

Thematics: Planetology and planetary systems

Description:

The SBI (Same Beam Interferometry) technique can provide very accurate measurements of the distance difference between two spacecraft or landing probes. It is a matter of simultaneously tracking in a coherent manner two or more landers having identical transponders from a single antenna on Earth. The transmitted radio signals are relayed by the lander transponder back to the Earth station, where they are recorded and then combined in an interferometric mode to form a differential phase measurement. Since the media traversed by the two signals (e.g. interplanetary plasma or the atmosphere of the Earth) are the same, these sources of error cancel out largely in the case of an SBI measure.

These measurements will make it possible to precisely observe the deformations of the surface of Mars due to the tides and its rotation, which will add precise constraints on the interior of Mars (such as the state and size of the core for example), as well as on the mass exchanges between the polar ice caps and the atmosphere.

For the proposed work, simulations will be carried out to quantify the contribution of this type of measure on our knowledge of the parameters of the rotation and tides of Mars. Measurements will be generated and then used to extract interesting information and assess the level of accuracy that will be achievable. This allows testing different mission configurations and seeing which is most conducive.

It will also be asked to test new configurations such as for example a lander on Mars, the second being on Phobos, one of the moons of Mars.

The software used was developed at the Royal Observatory of Belgium in the case of Doppler and SBI measurements between a Martian lander and the Earth. The orbital movement of Phobos around Mars will have to be added to the software and simulations will have to be carried out and analyzed for many configurations, in order to see which is the best mission strategy.

This work can lead to a scientific publication.

Whitening of Doppler data in Radio Science

Contact person: Véronique Dehant, co-promoter: Denis Grodent

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Availability: [take a rendezvous per email]

Thematics: Planetology and planetary systems

Description:

The Deep Space Network (NASA) and ESTRACK (European Space Tracking - ESA) ground stations communicate directly with space probes using uplink radio signals (Earth → Transponder) and downlink signals (Transponder → Earth). The frequency band used is often the X band or the S band.

When the Earth is in the field of the antennas of the probes and if the programmatic allows it, the probes transmit for a limited period of time telemetry data (navigation or sensors data) and / or scientific data (binary data or pure modulated tones). The scientific data of interest to us in this case are the Doppler data produced by the DSN and ESTRACK antennas after receiving the descending signals (One-Way path: Probe → Earth or Two-Way path: Earth → Probe → Earth).

The data stored in flat files are often temporally correlated and therefore require pre-processing so as not to overestimate the quality of the Doppler data with artificially small formal errors.

The objective of this master thesis is to apply a suitable data-whitening algorithm that will de-correlate and normalize the components of the Doppler signal embedded in background noise (Gaussian white noise).

Description of tasks:

- Examine the different whitening algorithms that allow to process highly noisy data and compare their respective performances.
- Implement under Matlab the algorithm of whitening that will minimize the amplification of the noise present in the Doppler data (files from DSN and ESTRACK ground stations).

This work can lead to a publication and cab be continued in a PhD thesis (application to real data).

Effect of charged particles on Doppler tracking

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Availability: [take a rendezvous per email]

Thematics: Planetology and planetary systems

Description:

The aim of this study is to analysis the effects of plasma turbulence in the solar wind on Doppler radio measurements from interplanetary spacecraft
A spacecraft receives an uplink signal at X-band (7.3 GHz), and transmits data (telemetry or science data) to Earth at X-band (8.4 GHz). In addition, a small amount of downlink power is transmitted at S-band (2.3 GHz) for evaluating the link performance. The two-way communication involves a 34-m ground station on the Earth that is equipped to emit an X-band signal and to receive both X- and S-band signals. At the ground station a loop tracker records carrier phase at both downlink carriers and this data is analyzed to examine the effect of charged particles, from solar plasma and the Earth's ionosphere, on Doppler passes typically used for tracking and navigation of interplanetary spacecraft. The Doppler tracking data allows, for example, calculating the gravitation field of the planet around which the spacecraft is orbiting. The experimental data set that will be used in this study are dual-frequency tracking of the European Space Agency's (ESA) Mars Express (MEX) spacecraft.

Task Description:

Based on the power spectral analysis of the dual-band data, the objective of this work is to determine an appropriate model for treating charged particles in single-band Doppler tracking. The statistic of phase variations will be described in terms of Allan variances (root-mean-square differenced-phase variations) and classical frequency variance. A realistic modelling of the charged particle variations should be adopted in good agreement with current models developed to estimate the solar plasma variations as a function of SEP angle.

This work can lead to a publication and can be continued in a PhD thesis.

Modelling climate and vegetation during glacial MIS 20 and interglacial MIS 19 periods using an Earth system Model of Intermediate Complexity

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Availability:
May : 14, 15, 23, 24, 28, 29, 30
June : 4, 5, 6, 28, 29

Thematics : Climate, environment and oceanography

Description:

During the Quaternary (i.e., the last 2.6 million years), the Earth's climate has been marked by gradual cooling and our planet entered into a succession of glacial and interglacial episodes. We are currently in the Holocene which is an interglacial that has lasted for 11,700 years already. The previous glacial period started more than 100,000 years ago and culminated 21,000 years ago during the last glacial maximum. The temperature or the ice volume during past periods is recorded by the oxygen isotopic abundance ($^{18}O/^{16}O$) in the calcite or aragonite shells of marine organisms that are deposited in marine sediments. The higher the $^{18}O/^{16}O$ ratio, the colder the climate (or equivalently the larger the ice volume) at the time the shell has been deposited. So, it is common to refer to glacial and interglacial periods of the Quaternary as marine ($^{18}O/^{16}O$) isotopic stages (MIS). The Holocene corresponds to MIS 1, which is the last minimum in the marine isotopic ratio, while the last glacial maximum, the last isotopic maximum, corresponds to MIS 2. These two isotopic stages have been widely studied with 3-dimensional climate and vegetation models, but earlier glacials and interglacials remain largely understudied from a modelling point of view.

In this master thesis, we propose to model MIS 20 and MIS 19, a succession of a glacial and an interglacial that happened approximately between 810,000 and 760,000 years ago. This time span includes the early to the middle Pleistocene transition (EMPT), when a shift in the astronomical periodicities of the climate signal has been recorded in the marine sediments. Indeed, before the EMPT, the dominant periodicity in the climate signal was the 40,000 year period of the obliquity, while later the dominant periodicity was the 100,000 year period of the eccentricity. The time span also includes the last reversal of the Earth's magnetic field, the Matuyama-Brunhes transition. Finally, MIS 19 has been recognized as the interglacial which is closest, from an astronomical (or insolation) point of view, to the Holocene. It can thus contain clues regarding to the stability of the current interglacial period. Some pollen data covering MIS 20 and MIS 19 have been published recently from a site (Montalbano Jonico section) in southern Italy.

The objective of the master thesis will be to simulate MIS 20 and MIS 19 with the Earth system model of intermediate complexity iLOVECLIM that has been recently coupled to the CARAIB dynamic vegetation model developed by our laboratory. This coupling is undertaken within a collaboration between our laboratory and the Laboratoire des Sciences du Climat et de l'Environnement (LSCE) in Gif-sur-Yvette, France. The results of the model over southern Europe will be compared to the pollen data of the Montalbano Jonico section.

Collaboration : Thomas Extier and Didier Roche, LSCE, Gif-sur-Yvette, France
Francesco Toti and Adele Bertini, University of Florence, Italy

Future ranges of tropical tree species under climate change : improving the predicting capacity of a dynamic vegetation model

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Availability:
May : 14, 15, 23, 24, 28, 29, 30
June : 4, 5, 6, 28, 29

Thematics : Climate, environment and oceanography

Description:

Climate change is expected to severely impact the distribution of plant species in the future on all continents. This may have huge consequences for the ecosystems and the services they provide to human populations.
Species range projections for the future are often made with niche-based models (NBM). These are statistical models that establish empirical relationships between the distribution of a species and the climate variables. Another type of model is also commonly used to project the impact of climate change on vegetation: the dynamic vegetation models (DVM). These models are process-based. They are most often used for large groups of plant species (the so-called plant functional types, PFT, such as, the needle leaf trees or the broadleaf deciduous trees in temperate regions), for instance to project the carbon budget of ecosystems into the future. However, a few DVM can be run at the species level. They can then become very powerful tools to project the current ranges of plant species into the future and to assess the risk of reduction of their distribution, or even the risk of species extinction, in the face of climate change. Indeed, these models integrate ecological and physiological processes governing the growth of the species. However, they need a careful calibration and validation at the species level, to increase their predictive capacity, since up to now these models have mostly been used at the PFT level.

Our laboratory has developed such a species-based DVM: the CARAIB model. A recent comparison of CARAIB with a NBM (MaxENT) for more than 50 tropical tree species of South America showed two phenomena.

First, the DVM projected clearly larger present-day distributions than the NBM. Now, NBMs are recognized for their good ability to project the realized niche (ecosystem position taking into account the biotic interactions) and the current distributions. This raised the hypothesis that the DVM is able to predict the fundamental niche of the species, i.e. the distributions when the species are not limited by their parasites or predators. The natural enemies constrain species distributions to their most favourable climatic regions, where also the species are the most efficient. Indeed, in these conditions, the plants are able to grow rapidly and to replace their injured parts and they produce more secondary metabolites allowing them to poison their predators. The first objective of the master thesis would be to test the efficiency of one or several climate constraints in the model on its predictive power.
Secondly, the predictive power of the DVM shrank when the number of presence coordinates was low (< 20). The coordinates allow the determination of bioclimatic thresholds. It is probable that the information with small numbers of presence data did not encompass enough the thresholds. This raised the hypothesis that the use of the density distributions of the climatic factors would allow to determine with more precision the bioclimatic thresholds. The second objective of the master thesis would be to test this hypothesis.

Collaboration : Alain Hambuckers, UR SPHERES, University of Liège, Belgium

Using remote sensing of vegetation to validate the gross primary productivity calculated by a dynamic vegetation model

Contact person : Louis François

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Tel : 04/3669776

Office: B5c 0/4

Availability:
May : 14, 15, 23, 24, 28, 29, 30
June : 4, 5, 6, 28, 29

Thematics : Climate, environment and oceanography

Description:

This master thesis will be performed in the framework of the BELAIR programme from the Belgian Science Policy (BELSPO). The objective of BELAIR is to develop test sites in various ecosystems in Belgium, where different datasets from remote sensing will be used and compared to ground data and modelling. A new site has been created within BELAIR to represent forest ecosystems. This site has been named BELAIR SILVA. It is located in the Belgian Ardenne, spanning the region comprised between Vielsalm and Eupen. Our laboratory is participating in the BELAIR SILVA consortium. Data will be collected over the site during 2018 with hyperspectral instruments embarked on drones and airplanes. Groundbased data on the vegetation will be acquired by our laboratory in collaboration with other partners of the consortium.

The objective of the master thesis will be to run simulations over the BELAIR SILVA area with our dynamic vegetation model CARAIB. This model calculates the leaf area index and the gross primary productivity, together with other characteristics of the vegetation, at the species level. The results of the model for key forest species will be compared to the ground data collected on the site and to the hyperspectral data collected by the instruments embarked on the drones and airplanes. A comparison can also be undertaken with satellite data (e.g., MODIS, SENTINEL). The student will participate in the ground data acquisition.

Collaboration : Alain Hambuckers, UR SPHERES, University of Liège, Belgium
BELAIR SILVA consortium, Belgian Science Policy (BELSPO)

Spatio-temporal variability of eddies in the vicinity of the Gulf Stream

Contact persons: Sylvain Watelet, Jean-Marie Beckers (GHER)

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Office: B5a, 2/12

Availability: Preferentially monday's afternoon.

Thematics : Climatology, Oceanography

Description:

Ocean currents are often represented as straight flux lines between large scale gyres. For instance, the mean Gulf Stream path separates from the US east coast at Cape Hatteras and then flows between the subtropical and subpolar gyres towards the central North Atlantic from where its extension to the European and Arctic seas is known as the North Atlantic Drift. Although the mean path of the Gulf Stream has been studied for centuries (already observed in the 16th century), its spatio-temporal variability and their causes are still subject to some debate. In particular, it was discovered in 1947 that rings typically smaller than 100 km are generated from the cut-off of Gulf Stream meanders. On its northern side, the Gulf Stream releases warm-core eddies rotating clockwise while cold-core eddies rotating anti-clockwise are generated on its southern side. These eddies have a large impact on Gulf Stream heat transport and more generally on marine biology or even hurricanes strength. Although the recent arrival of satellites greatly improved our knowledge of their structures, the studies on Gulf Stream eddies are often limited to short time periods. Besides, satellite data only allow the study of the ocean surface while most ocean climate models have a coarse resolution (~1°) and are thus not « eddy-permitting ». Here, in the frame of an ongoing PhD thesis at GHER, very high resolution fields of temperature, salinity, surface height and speed from DRAKKAR simulations at 1/12° will be made available to the master student. These fields available for the period 1970-2015 will be used to detect the eddies, characterize their spatial variability and highlight possible trends. The teleconnections between the atmospheric forcings (NAO,…) and these ocean turbulences might be studied as well.

Interpolation of SWOT altimetry data using variational methods

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Office: B5a, 2/11

Availability: Afternoon except Wednesday.

Thematics : Oceanography (remote-sensing)

Description:

SWOT stands for Surface Water and Ocean Topography (https://swot.jpl.nasa.gov/) is a mission focused the world's oceans and its terrestrial surface waters. The SWOT satellite will provide ocean surface measurements with an unprecedented resolution, over a 120 km wide swath with a ~20 km gap along nadir. This particular spatio-temporal data distribution makes it necessary to use specific interpolation techniques to create gridded fields of sea surface height.

While the satellite is expected to be launched in April 2021, the SWOT simulator (https://github.com/SWOTsimulator) already provides artificial SWOT measurements on sea surface height with simulated errors based on numerical ocean simulations. Such a dataset could be used to perform some tests in order to prepare for the real data coming after the satellite deployment.

The proposed work consists in:
1. Making an inventory of the interpolation techniques usually applied to altimetry data and to simulated SWOT measurements.
2. Apply the DIVAnd (https://github.com/gher-ulg/divand.jl) tools on simulated SWOT data in a selected region and assess:
   - the computation time,
   - the quality of the gridded fields and
   - the estimation of the analysis parameters.

Simulating Tsunami propagations

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Availability: Preferentially monday's afternoon.

Thematics : Oceanography

Description:

Since the Sumatra 2004 disaster, Tsunami alert systems have been implemented in a series of places, including models for Tsunami-wave propagation. The proposed work will provide an assessment of the associated uncertainties.

The work will start with an analysis of the different mathematical models used to simulate Tsunami propagation (linear models, Boussinesq models, ray-tracing models). One model will be selected to provide a realistic simulation of the Sumatra case. A baseline simulation, reasonably close the Sumatra case, will then serve to analysis how uncertainties on the model formulation (including or not the non-linearity of the Boussinesq model), topographic uncertainties or the initial shape of the perturbation lead to different predictions. To do so, one has on the one hand side to define a strategy to create perturbed simulations and on the other hand to defined adequate metrics (moment of wave arrival, amplitude, …).

The outcome will then be an estimate of errors in the Tsunami propagation model.

The work will rely on a good understanding and analysis of fundamental geophysical fluid dynamics and the use of a numerical model.

Implementation of a tri-dimensional modelling framework for understanding and predicting Suspended Particulate Matter dynamics along the Scheldt Estuary

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Availability: Better to send an email to agree on a meeting

Thematics : Environment and oceanography

Description:

In recent decades, the Scheldt estuary has been affected by diverse anthropogenic impacts like eutrophication and dredging activities. A sound management of the estuary dredging activities requires the development of advanced modeling tools that will allow to understand and predict the dynamics of suspended particulate matter (SPM). In this master thesis, it is proposed to apply a three-dimensional hydrodynamic model of the Scheldt that will investigate the SPM dynamics from interannual to daily time scales in response to tides, waves, river discharges, wind/bottom-induced turbulence, transport, deposition and erosion of SPM. The master thesis will be integrated in an ongoing effort to build a model that fully couples the Scheldt and North Sea region to provide a refined description of the dynamics (e.g. retention, transformation, export, sinking) of materials along the Scheldt-Belgian coastal Zone continuum as well as a better quantification of the exchanges of SPM between the two systems.

Development of a spectral radiative module for oceanographic models

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Thematics : Environment and oceanography

Description:

The master thesis is targeted towards the development and implementation of a computationally efficient radiative transfer model (RTM) describing the distribution of in-water irradiance (the diffuse and direct parts) along the vertical and in different spectral bands corresponding to those typically used in remote sensing and in particular in the Sentinel 3 Ocean and Land Color Instrument (OLCI). The penetration of spectral irradiance will be described considering its absorption and scattering at different wavelengths by various optically active components. State of the art formulations that link absorption and scattering properties to the biomass of optically active constituents will be used. The main purposes here are 1) to obtain a better estimation of the in-water irradiance that is expected to improve the quality of model predictions (biogeochemistry and physics) and 2) to simulate radiometric properties that can be directly linked to observations, and exempt validation/calibration/assimilation efforts from the use of empirical equations that link observations and modelled variables (e.g. the equation that links reflectance to chlorophyll-a). The approach will be validated using radiometric measurements provided by remote sensing and field data like BGC-ARGO, AERONET-OC and BIOMAP products.

Quantifying the global ocean deoxygenation process

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Thematics : Environment and oceanography

Description:

Oxygen concentrations in both the open-ocean and coastal waters have been declining since at least the middle of the 20th Century. This oxygen loss – or deoxygenation – is one of the most important changes occurring in an ocean increasingly modified by human activities that have raised temperatures, CO_2 levels, and nutrient inputs, and have altered the abundances and distributions of marine species. Analyses of direct measurements at sites around the world indicate that oxygen minimum zones in the open ocean have expanded by several million km^2 and that hundreds of coastal sites now have oxygen concentrations low enough to limit the distribution and abundance of animals and alter the cycling of important nutrients. The aim of the master thesis is to quantify the global oxygen loss using oxygen data available in open databases and the DIVA interpolation software. Data provided by autonomous ARGO floats will be integrated as well.

Additive Manufacturing: a tool for innovative space optics

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Availability: Please contact by mail and we'll find a date.

Thematics : Instrumentation and methods

Description:

Additive manufacturing (AM) is now well implemented in several space domains, even for launchers. The potential of new component shapes is well known. Moreover, AM allows for including new function on elements by e printing. In the field of space optics, this can be used for including electrical function for thermal control, grounding, sensors… Innovative deployable optics could also benefit from those new degree of freedom (inserting piezoelectric control or sensors in mechanical or optical parts…).
Those research fields are still in a very preliminary phase. The goal of the Master Thesis would be double:

1. Make a complete survey of the existing solutions based on AM with augmented functionalities (e printing…) for optics (with a focus on space optics).
2. Based on the compilation, propose innovative combinations regarding miniaturization of components and especially the potential application in CubeSat.

This study would be conducted in the frame of the Cubesat development at ULiege (Oufti) and in close contact with the Centre Spatial de Liège activities.

Oufti 2 Radiation Payload simulation

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Thematics : Earth radiation environment and radiation simulation

Description:

In the frame of Oufti 2 a radiation measurement payload will measure radiation dose and effects.
The goal of this work would be to simulate radiation environment of OUFTI 2 (with SPENVIS online tool), and evaluate the foreseen measurement of on-board rad payload and to optimize the data acquisition rate.