

## **FRIA CALL 2025**

**FRIA 1ères bourses [FRIA-B1] / FRIA (1st grants) [FRIA-B1]**

**Application ID :** 40038239

**Host institution:** Université de Liège

**Participants:**

**MIFTAH Mohamed Amine [Applicant]**

JEHIN Emmanuel (ULiège) [Promoter]

**Titre de la proposition :**

*Modélisation optique et radar de la forme des astéroïdes géocroiseurs*

**Proposal title:**

*Optical and Radar Shape Modelling of Near-Earth Asteroids*

## **Eligibility**

### **Degree giving access to the grant**

<b>Graduation date (or expected graduation date) of your master degree or equivalent</b>	20/07/2023
<b>Level of your master degree or equivalent</b>	Advanced master
<b>Field of your master degree or equivalent</b>	Sciences except for Tourism Studies and Management
<b>Country where the degree was or will be awarded</b>	Morocco
<b>Are you a doctor or a veterinary doctor?</b>	No

### **Number of childbirths/adoptions**

<b>Please indicate the number of childbirths (including 0)</b>	0
<b>Number of adoptions (including 0)</b>	0

## **Researcher's identification**

### **Researcher's profile**

<b>Last name</b>	Miftah
<b>First name</b>	Mohamed Amine

Other given name(s)	-
Date of birth	05/01/2001
Gender	Male
Nationality	Morocco

## Phone number(s)

Professional phone number	+212627328398
Mobile professional phone number	+212627328398
Private phone number	+212627328398
Private cellular phone number	+212627328398

## Your diplomas

### Diplomas:

Date of award	Diploma	Institution
24/07/2023	<b>Master 240 Sciences</b> Physique des hautes energies, astronomie et physique computationnelle <b>Mention</b> : Bien <b>Thesis</b> : Analyse des courbes de lumière des astéroïdes avec les télescopes TRAPPIST <b>Promoter</b> : Emmanuel Jehin/ Jabiri Abdelhadi <b>Mention</b> : Bien	Université Cadi Ayyad (Maroc)
26/07/2021	<b>Licence Sciences</b> Licence d'Etudes Fondamentales parcours physique moderne <b>Mention</b> : Passable	Universite Cadi Ayyad (Maroc)

## ORCID ID number

If you have an identification number on the ORCID platform, you can indicate your ID number.	0009000312206532
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## Position(s)

### Career:

Position	Institution / Company	Position starting date	Position end date
Doctoral Fellow [Boursier de doctorat]	Université de	07/12/2024	30/06/2025

Full time (Erasmus+)	Liège		
Enquêteur Full time	Haut- Commissariat au Plan Marrakech Maroc	01/09/2024	30/09/2024
Enseignant de physique-chimie au Lycee technique Mohamed VI Full time	Association alahd al Jadid Marrakech Maroc	01/01/2024	30/04/2024

## Type of Grant

### Information on the type of the requested grant

Number of previous applications submitted for this instrument (including 0)	0
Type of grant for which you are applying	1st grant 1st year

### Have you already worked on your PhD thesis, on this topic precisely ?

Have you already worked on your PhD thesis, on this topic precisely ? If yes, indicate the number of months on a full-time equivalent basis. If not, indicate 0.  <i>Note: if your thesis is an extension of your master's dissertation, please do not take into account the research period of your master's dissertation e.g. if you have worked during 18 months at 50%, please indicate 9</i>	7
I certify that by October 1st, I won't have worked or I will have worked full time for less than a year on the PhD project that I am submitting	Yes

### Thesis already started:

From	To	% d'occupation	Did you obtain a grant/compensation?	Funding source (if applicable)
07/12/2024	30/06/2025	100 %	Yes	Erasmus+ 7 months (ULiège)

### Start date of the grant

If you expect your grant to begin after 1st October of the year of the call,	-
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please indicate the date foreseen	
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## Framework

### Host institution

Host institution where the research programme will be pursued	Université de Liège
Graduate school	Sciences

### Promoter

Informations
Jehin Emmanuel ejehin@uliege.be Université de Liège

### Co-promoter

Does your proposal include a co-promoter? <i>The co-promoter has to be at the postdoctoral level and belong to one of the institutions listed in Appendix 1 (of the rules and regulations)</i>	No
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No data

### Joint supervision

Do you plan to prepare your Ph.D. under joint supervision? <i>Scientific collaboration with co-graduation during full doctoral studies within both universities based on the same research work. This leads to a double degree obtained within both universities involved.</i>	Yes
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What type of co-supervision is this?	Supervisor
With another institution (Flanders, foreign...)	Jabiri Abdelhadi Professeur jabiri@uca.ac.ma Cadi Ayyad University Marrakech (Maroc)

## Miscellaneous

### Artificial intelligence

Did you use generative Artificial Intelligence (AI) tools and/or other AI-assisted technologies in the preparation of this application? This statement does not apply to syntax and spell checking.	No
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## Project description

### Research project : general information

Main language of the proposal	English
During the interview, in which language do you wish to defend your project?	English
Title of the project in French	Modélisation optique et radar de la forme des astéroïdes géocroiseurs
Title of the project in English	Optical and Radar Shape Modelling of Near-Earth Asteroids
Shortened title or acronym of the proposal	NEA Shape

#### Abstract of the project in French

Les astéroïdes sont des vestiges du système solaire primitif qui contiennent des indices essentiels sur la formation planétaire, l'évolution dynamique du système solaire et même l'origine de la vie sur Terre. Pourtant, malgré leur importance, la connaissance détaillée de leurs propriétés physiques, formes, états de spin et caractéristiques de surface reste limitée à une petite fraction de la population connue. Cette recherche vise à caractériser un échantillon significatif d'astéroïdes géocroiseurs (NEA) soigneusement sélectionnés, grâce à une approche combinée basée sur la photométrie au sol, l'imagerie radar et les observations polarimétriques. Au cours des quatre prochaines années, nous mènerons des campagnes d'observation photométrique dense à l'aide des télescopes TRAPPIST de l'ULiège afin d'obtenir des courbes de lumière précises. Nous extrairons les périodes de rotation et construirons des modèles de forme convexes 3D grâce à des techniques d'inversion des courbes de lumière. Ces modèles seront ensuite affinés à l'aide de données radar provenant des archives de l'observatoire d'Arecibo, grâce à une collaboration unique avec l'équipe de l'Université de Floride (UCF). L'ensemble de données combinées nous permettra de produire des modèles de forme détaillés, de déterminer les volumes et d'étudier l'effet YORP, un phénomène mal compris où le rayonnement solaire modifie subtilement la vitesse de rotation d'un astéroïde. Notre objectif est de modéliser une vingtaine de NEA soigneusement sélectionnés, doublant ainsi le nombre d'astéroïdes ayant aujourd'hui un modèle de forme dérivé du radar. Ces modèles alimenteront également les études polarimétriques en cours, qui nécessitent des volumes précis pour calibrer la relation albédo-polarimétrie, améliorant ainsi les estimations de l'albédo et de la rugosité de surface, des données essentielles pour la défense planétaire et la modélisation des risques d'impact.

#### Abstract of the project in English

Asteroids are remnants of the early solar system that carry critical clues about planetary formation, dynamical evolution, and even the origin of life on Earth. Yet, despite their importance, detailed knowledge about their physical properties, shapes, spin states, and surface characteristics remains limited to a small fraction of the known population, largely due to observational constraints. This research aims to contribute to filling this gap by characterizing a significant sample of carefully selected Near-Earth Asteroids (NEAs), using combined approach based on ground-based photometry, radar imaging, and polarimetric observations. Over the next four years, we will carry out dense photometric observing campaigns using the TRAPPIST telescopes of the University of Liège to derive precise lightcurves. We will extract rotational periods and build 3D convex shape models using lightcurve inversion techniques. These models will then be refined using the radar data from the Arecibo Observatory archive, thanks to an active collaboration with the radar team of the University of Central

Florida. The combined dataset will allow us to produce detailed shape models, determine volumes, and investigate the YORP effect, a poorly understood phenomenon in which solar radiation subtly modifies an asteroid's spin rate. Our goal is to model around twenty carefully selected NEAs, effectively doubling the number of radars derived asteroid shapes available today. These models will also feed into ongoing polarimetric studies that need accurate volumes to calibrate the polarimetry albedo relationship, enhancing albedo and surface roughness estimations, key inputs for planetary defense and impact risk modeling.

Does your research project encompass an interdisciplinary approach?	No
Did you submit a funding application to the F.R.S.-FNRS via the same instrument in the past ?	No

### Uploaded file : Research project:

<b>Project proposal</b>
FRIA_B1_partie_scientifique_Miftah.pdf (21/08/2025 - 824.156 kB)

## Jury

PE9 - Astro-physics/-chemistry/-biology; solar system; planetary systems; stellar, galactic and extragalactic astronomy; cosmology; space sciences; astronomical instrumentation and data • PE9 - jury 1

## Descriptors

- PE9 - Astro-physics/-chemistry/-biology; solar system; planetary systems; stellar, galactic and extragalactic astronomy; cosmology; space sciences; astronomical instrumentation and data PE9\_2 - Solar system science (Relevancy: High)
- PE9 - Astro-physics/-chemistry/-biology; solar system; planetary systems; stellar, galactic and extragalactic astronomy; cosmology; space sciences; astronomical instrumentation and data PE9\_13 - Astronomical instrumentation and data, e.g. telescopes, detectors, techniques, archives, analyses (Relevancy: High)
- PE9 - Astro-physics/-chemistry/-biology; solar system; planetary systems; stellar, galactic and extragalactic astronomy; cosmology; space sciences; astronomical instrumentation and data PE9\_4 - Astrobiology (Relevancy: Medium)

If you chose only one descriptor relevant to your subject area selection, please justify it

-

Optional: in case you are conducting a sustainable development-oriented research project, you can select a descriptor listed in the drop down menu below	-
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### Unrestricted keywords

Asteroids, light curves, photometry, TRAPPIST, Arecibo Observatory, radar images, shape model

## Ethical aspects

Does your research involve experiments or samples on human being/material ?	No
Does your research involve the use of	No

experimental animals ?	
Does your research involve ethical issues related to Human Sciences ?	No

## Other information

### Scientific seniority

<b>Scientific seniority</b> <i>Effective duration (in years) of research and development activities carried out from the date the diploma (master) which gives access to the requested funding was awarded.</i>	0
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### Cursus details

Uploaded file : Cursus details:

Cursus details
detail_cursus.pdf (20/08/2025 - 44.599 kB)

### Ranking

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Ranking
classement_doctorant.docx-1.pdf (20/08/2025 - 573.622 kB)

### Scientific awards and honours

Name of the award or honours	Institution/Company name	Awarding year
1st place in the Pre-Plancks national theoretical physics competition	Universite Mohamed V, Moroccan association of physics	2022
Major de promotion 2021-2023 du Master Physique des Hautes Énergies, Astronomie et Physique Computationnelle.	Universite Cadi Ayyad	2023

### Periods of inactivity

Over the last 5 years, have you been professionally inactive for more than 2 months?	No
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### Publications

Do you have any publications ?	Yes
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Uploaded file : Publications:

List of publications
Publications and communications of Mohamed Amine Miftah.pdf (20/08/2025 - 42.343 kB)

Uploaded file : Publication - full text:

Publication - full text
2024MPBu...51...pdf (04/08/2025 - 491.952 kB)
aa54476-25.pdf (19/08/2025 - 2053.876 kB)

## Master thesis

Master thesis:

Master thesis
Memoire_Mohamed_Amine_Miftah.pdf (04/08/2025 - 6664.494 kB)

## Research stays completed (mobility)

Please indicate your research stays of more than 30 days **completed** outside your main host institution

Previous research stays:

No data

## Planned research stays (mobility)

Please indicate your research stays of more than 30 days **that you plan to do** outside your main host institution

Planned research stays:

From	To	Information about the research stay
02/02/2026	06/04/2026	Florida Space Institute at University of Central Florida (UCF) Orlando (United States) This 2 months stay will allow me to work with the Florida Space Institute team (at UCF) and particularly Dr M. Ferrais and F. Venditti, who are among the world specialists of radar shape modeling

## Additional courses

Additionnal courses:



No data

## Additional scientific activities

### Additional scientific activities

+ May 12 to 16, 2025 - Asteroid Radar Modeling Workshop 2025 (ARMW25): I have participated to a one week workshop in Oviedo (Spain) about asteroid shape modelling at the University of Oviedo (Spain) and co-organized by the Florida Space Institute (UCF). I learned how to use the SHAPE program.  
Other workshops and visio-conference meetings are planned in the future .

+ September 7 to 12, 2025 - EPSC-DPS joint meeting in Helsinki. I will participate to this large meeting to present my first results about asteroids 2002 KL6. The goal of the congress is to cover a broad range of science topics related to planetary science and planetary missions.

## Academic Referees

### Academic Reference persons:

#### Informations

Carry Benoit  
benoit.carry@oca.eu

Venditti Flaviane  
venditti@ucf.edu

## Justification for the prospects of industrial or agronomic applications

Does your doctoral work have short, mid, or long-term of industrial or agronomic applications prospects?

No

Description and justification of the prospects (If there are no prospects, please indicate "Not applicable")

non applicable

## Referees external to the academic world

### Non academic Reference persons:

No data

## Appendices

### Appendices

Please upload the required appendices **in PDF format**

Appendices can be uploaded into your form until the validation date of your form. If some documents listed hereunder are not in your possession by the date of validation of your application, they may be uploaded on your e-space page until 30/09/2025 at the latest. After the validation deadline for the applicant, the F.R.S.-FNRS will send you an e-mail including all practical information related to your application (documents to upload etc.).

## Certificate of achievement or Diploma

- This document is strictly confidential

version : 21/08/2025 - Page 9/10

Uploaded file : Copy of the degree:

**Certificate of achievement or Diploma**

Master\_Mohamed\_Amine\_Miftah.pdf (20/08/2025 - 404.562 kB)

## PhD access certificate

Uploaded file : PhD access certificate:

**Certificate of access to the doctorate or certificate of registration for the doctorate**

attestation-inscription-uliege\_Miftah.pdf (20/08/2025 - 276.923 kB)

## Certificate of registration for the specialization

Certificate of registration for the specialization:

No data

**Annexe : Parcours académique par année d'études (Etudes supérieures)****Academic record per year of study (higher education studies)**

Complétez le tableau suivant par année d'études en commençant par la première année académique (incluant les années non réussies ou abandonnées).

Please complete the table below detailing your academic record per year, starting with the first year of study, including failed and aborted years of study.

<b>Année académique</b> <i>Academic Year</i>	<b>Intitulé de l'année d'études</b> <i>Course Title for each year of study</i>	<b>Nombre de crédits acquis<sup>1</sup></b> <i>Credits obtained<sup>1</sup></i>	<b>Résultats obtenus</b> même en cas d'échec <i>Results or class obtained, including failure</i>	<b>Date de proclamation</b> <i>Graduation Date</i>	<b>Institution</b> + pays <i>Institution</i> +country
2016-2017	Ex. : 1 <sup>ère</sup> année Bachelier Histoire / Bachelier Histoire (Bloc annuel 1) ...	Ex. : 45/60	Ex. : Ajourné, Bien, Distinction, Sans Mention, 76%, 13/20, ...	30/06/2019	Ex. Université de Bologne (Italie)
2018-2019	1 ère année Filière Sciences de la Matière Physique	11.4/20	passable	01/07/2019	Universite Cadi Ayyad (Maroc)
2019-2020	2 ème année Filière Sciences de la Matière Physique	11.8/20	passable	01/07/2020	Universite Cadi Ayyad (Maroc)
2020-2021	3 ème année Filière Sciences de la Matière Physique/Parcours Physique Moderne	11.5/20	passable	29/07/2021	Universite Cadi Ayyad (Maroc)
2021-2022	1 ère année Master Physique des Hautes Energies, Astronomie et Physique Computationnelle	14.6/20	Bien	20/07/2022	Universite Cadi Ayyad (Maroc)
2022-2023	2 ème année Master Physique des Hautes Energies, Astronomie et Physique Computationnelle	14.4/20	Bien	26/07/2023	Universite Cadi Ayyad (Maroc)

<sup>1</sup> par rapport au nombre de crédits théoriques (si applicable) / based on the number of ECTS credits required (if applicable)

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Full name of the applicant	Mohamed Amine Miftah
e-spacereference	40038239

## SCIENTIFIC SECTION OF THE PROPOSAL

MAIN LANGUAGE CHOSEN = ENGLISH

This part includes the following elements:

1. Description of the research project
2. Comments on changes made in the research project in case of resubmission (optional)
3. Activities report on the first year of doctorate (**ONLY** for 1<sup>st</sup> grant - **2<sup>nd</sup> year**)\*
4. Potential interdisciplinary approach of the research project (optional)
5. Description of the work environment
6. Summary of the master's thesis or equivalent
7. Additionnal comments (optional)
8. Ph.D. work calendar per month

**\* “1<sup>st</sup> grant - 2<sup>nd</sup> year” applicants have already worked on a full-time basis for one year full time equivalent on the Ph.D. project submitted to the FRIA.**

**The applicant must fill in the sections below and convert the file into an unprotected PDF before appending it to the online application form.**

The F.R.S.-FNRS insists on **strict compliance with the instructions given for each part of the proposal** (scientific section relevant to the instrument selected, number of pages allowed for the documents to be enclosed with the application form...) and stresses again the sovereign consideration of the juries in case the file would exceed the applicable page limit.

# 1. DESCRIPTION OF THE RESEARCH PROJECT

*The written project must be made up of 4 parts (max. 4 pages) according to the structure below, accompanied by a reference bibliography (max. 1 page besides the 4 pages dedicated to the project) listed by order of appearance within the text.*

*Graphs and tables may be added (max. 2 pages).*

[Enter text here. Format: Arial 12, single space]

## 1.1 Goals of the research

Asteroids are the leftovers of the material that accreted to form the planets in the early stages of the solar system. The initial conditions in the solar nebula and its subsequent evolution have shaped the present state of the solar system. The asteroids that survived the formation of the planets have undergone dynamical, thermal and collisional events, making the study of asteroids populations as well as individual asteroids a unique opportunity to unravel the mysteries around the fundamental questions about the formation and the evolution of our solar system (Morbidelli et al, 2015).

Asteroids are located in different regions in the solar system. The Main Belt of Asteroids (MBA) is the largest reservoir of asteroids, located in the region between Mars and Jupiter. The Jupiter Trojans are in the Lagrange points of Jupiter and the Near-earth asteroids (NEAs) are those coming close to the Earth. The study of these populations helps answer several important questions regarding solar system formation models (Bottke et al. 2002) and to assess the threat posed by the ones orbiting in the vicinity of the Earth. Due to the long evolutionary history of these objects, they exhibit a large variety of shapes, compositions and orbit distribution, thereby providing clues to fundamental questions about the solar system: how their compositions were altered? What were their birthplaces? What was the rate of collisions? What roles did they play to bring life on Earth in the astrobiology context?

In order to answer all these questions, many observation campaigns, sky surveys, and space missions have been carried on in the last decade to study them in depth. However, our current knowledge is severely limited by observational constraints due particularly to their very small sizes and/or large distances. Because of that, statistical analysis of asteroids populations is often affected by observational biases (DeMeo and Carry 2014). For instance while being a fundamental property, the internal structures of asteroids are mostly unknown, with the exception of the few that have been visited by a space probe or in the case of binary asteroids. As a consequence, very little is known also about most of the NEAs as they are often observable only during a small period of time when they are close to the Earth and cross the sky very fast. Because of the wide variety and irregular shapes of these objects, only a few were modeled making the planetary defense program still behind compared to the numerous NEAs that are discovered every day. Given this unsatisfactory situation, efforts still need to be done in order to characterize as many of them as possible. By passing close to the Earth NEAs offers a unique way to get precise shapes and volume of asteroids via radar observations which are not possible for asteroids very far away in the Main Belt.

The goal of the present research is to contribute to this effort, particularly in the planetary defense context, using a combination of ground-based photometric, radar and polarimetric observations linked to modeling capabilities. We propose first to use the two TRAPPIST robotic telescopes, from the Liège University (Jehin et al. 2011), to carry out in the next four years regular and dense photometric observations (in various filters) of a carefully selected sample of NEAs. Those observations, complemented by the extensive TRAPPIST database, will allow us to obtain precise light curves (0.01 mag) of our targets at various phase angles. This will allow us to derive the asteroids rotation periods and compute their 3D convex shape models using the light curve inversion technique (Kaasalainen and Torppa. 2001). These data will then be combined with radar

observations from the Arecibo observatory (AO) archive to which we have special access, thanks to a unique collaboration with the radar team of the Florida Space Institute (at UCF) in the US. In the framework of these collaborations we will during our thesis take care of the data reduction and analysis of the AO radar observation to get a precise shape, volume and YORP effect (Bottke Jr et al. 2006) using the SHAPE modeling software (Magri et al. 2007). These information will also be combine with polarimetric observations for several of them to precisely determine their surface properties.

## 1.2 State of the art

NEAs are a valuable resource for understanding the solar system's formation and evolution. They represent a diverse population of objects originating from various regions of the solar system (Granvik et al. 2018) and are more accessible to space missions than their parent bodies (Shoemaker & Helin. 1978). NEAs are also thought to have played a crucial role in delivering water and prebiotic molecules to early Earth (Lauretta et al. 2015). This hypothesis has gained further support from recent findings by the Japanese Hayabusa2 mission, which collected samples from the asteroid Ryugu (Oba et al. 2023).

Asteroids pose also a significant threat to Earth. In particular, NEAs follow orbits that bring them close to our planet, and some have the potential to cause catastrophic impacts (Mathias et al. 2017). Understanding their physical properties, trajectories, and especially their shapes and composition is therefore crucial. Detailed knowledge of an asteroid's shape helps space missions to better plan landings and surface operations, improving mission safety and success. Additionally, this information is vital for planetary defense strategies, such as the use of kinetic impactors demonstrated in NASA's DART mission (Rivkin et al. 2021). Moreover, an accurate determination of the albedo, density and surface roughness of NEAs are crucial not only for assessing potential damage in the event of an impact, but also for validating the ground impact models (Motiwalla et al. 2015). Studying these characteristics is important not only for advancing scientific knowledge by performing population studies, but also for protecting Earth and ensuring long term human safety.

Due to both their scientific importance and the potential hazard they represent, NEAs have become the focus of recent space missions. A key motivation for these missions is planetary defense improving our ability to detect, characterize, and mitigate potentially hazardous asteroids. As Thomas H. Burbine emphasized: "It is certain that the Earth will be hit in the future by an asteroid. The only question is: when?" (Burbine, 2002). In the event of an imminent impact, there will not be sufficient time to deploy a space probe to study the asteroid's properties. Therefore, ground based observations and the accurate and fast interpretation of the data they provide, as proposed in our work, is critically important.

At the time of writing this proposal, only around 30 NEAs have had detailed shape models derived from radar observations. Given the importance of this technique for detailed characterization, we propose to model approximately 20 more targets (see Table 1). This effort would effectively double the number of NEAs studied using radar derived shape modeling, significantly expanding the dataset available to better understand the diversity in NEA morphologies, rotational states, and dynamical evolution. Our results will also support broader scientific goals by contributing to polarimetric studies, in collaboration with the polarimetry team at UCF. This will enable improved estimates of albedo of our targets and thus their surface roughness, thereby enhancing our understanding of small body populations and informing future planetary defense, exploration strategies and studies of solar system evolution.

## 1.3 Research project

**TRAPPIST light curves:** Photometric observations of NEAs provide valuable insights into their rotational properties and shapes. This technique involves measuring variations in brightness over time, primarily caused by the asteroid's rotation around its spin axis combined with its irregular

shape. As a result, rotating NEAs exhibit characteristic light curves from which the rotation period and the global 3D shape can be determined (Kaasalainen and Torppa. 2001).

Using the TRAPPIST robotic telescopes, we have already acquired and will schedule hundreds of photometric measurements of carefully selected NEAs (see Table 1). I will perform aperture photometry on the collected data and construct light curves using the Photometry Pipeline software (Mommert, 2017), and python scripts which I developed during my master's thesis and during the seven months spent at ULiège thanks to an Erasmus+ grant. An example of a rotational phase light curve obtained for the NEA (154244) 2002 KL6 is shown in Fig.1 (Miftah et al., in prep). While spatially unresolved data lack the detail of disk-resolved imaging, they still yield critical information as they can be obtained at much longer time span and wider viewing geometries. The asteroid's rotation period can be extracted through Fourier analysis, with scripts that I have already developed to perform this task. Moreover, using the BVRI filters we are able to compute the color indices and thus estimate the spectral classification of our targets (which gives indication of its surface composition).

By combining light curves obtained at different viewing geometries and solar illumination, which is especially the case when the NEA is close to the Earth, it becomes possible to reconstruct the object's 3D shape and spin axis orientation. This is achieved through the light curve inversion method introduced by Kaasalainen and Torppa (2001) and further developed in Kaasalainen et al. (2001). I used that technique already for example in the test case I have carried on in Liège to derive the shape and spin state of 2002 KL6 as illustrated in Fig. 2 (Miftah et al., in prep). Although the light curve inversion technique produces a reliable convex model that generally aligns with the actual shape of asteroids, it remains a simplified global shape that cannot capture surface concavities, like large craters which are features commonly found on asteroids and, unfortunately, it provides no information about the true volume of the object. However, using the resulting spin parameters and 3D shape as initial input of a more detailed shape modeling, using radar is extremely useful as it makes the modeling process simpler, faster, and more robust. This is the reason why new light curves obtained with TRAPPIST and combined with the existing archival radar data from Arecibo have such great synergy.

**Modeling real shapes and YORP effect:** Radar observations will serve as a crucial complement to photometric data in this project. Radar allows for the acquisition of high-resolution images of NEAs, which is particularly valuable for reconstructing their 3D shapes and resolving surface features in much greater detail than photometry alone (Magri et al. 2007). When NEAs pass near the Earth, ground-based radar facilities, such as Goldstone and the Arecibo Observatory until recently, can generate detailed surface maps of these objects.

This technique involves transmitting radio waves towards the asteroid, whose surface returns them with time delays that depend on the shape and topography of the object (Ostro, 1993). Additionally, due to the asteroid's rotation, the reflected signal experiences Doppler shifts. Regions rotating toward the observer produce higher-frequency reflections, while those rotating away produce lower frequency signals.

The Arecibo Observatory has observed about 1,000 NEAs since 1963, but only a small fraction of these have already been modeled in detail. The goal of this study is to expand the number of modeled NEAs, focusing on the targets listed in Table 1. This list was obtained from the following criteria: 1) objects were observed at Arecibo and resulting in disk-resolved delay-Doppler images; 2) no published or on-going radar-based shape or spin model yet; 3) have already been observed with TRAPPIST or will be observable between 2026 and 2029 with an apparent magnitude  $V < 17$  mag. During the thesis, we will collaborate with the UCF radar team which will give us a privileged access to the Arecibo archival data. The obtained models will then be used to study 1) the distribution of shapes among NEAs (top-spin, elongated, contact binary, etc.); 2) the distribution of spin parameters (rotation period and spin axis orientation); 3) the distribution of YORP effect.



The YORP effect (Yarkovsky O'Keefe–Radzievskii–Paddac) is a poorly understood phenomenon where solar radiation alters the spin rate of an asteroid, either accelerating or decelerating it over time (Bottke Jr et al. 2006). Interestingly, all the 12 confirmed cases of YORP so far have shown spin up behavior (Durech et al. 2024), with only one known exception (Rodríguez Rodríguez Javier, et al. 2024). This exceptional case is 2002 KL6 that I'm studying since a few months. I already determined the combined shape from photometric and Arecibo observations as a test case for my thesis and that I will present at the EPSC-DPS joint 2025 conference (Fig 2 and Fig 3). I'm using the SHAPE software and dedicated scripts, and at the time of writing this proposal I am adding data from Goldstone radar observations to fine tune the shape and investigate the YORP effect. One goal of this research is to determine whether the observed spin up bias is due to limitations or selection effects in current observational data, or if it reveals a gap in our theoretical understanding. Through a population study of our NEAs using both radar and photometric techniques, this project aims to assess the consistency of current YORP models, explore its role in the formation of binary or multi-component asteroids, and ultimately contribute to a broader understanding of the dynamical evolution of small bodies in the solar system. In addition to this work, our 3D shapes will be shared with the team working on polarimetry in UCF, as they need accurate volumes to calibrate the polarimetry albedo relationship that is important for planetary defense and assessing the impact models (Ferrais et al. 2023)

## Work plan

**Year 1 (2025 – 2026):** Proceed with the preparation and refinement of the combined shape model for 2002 KL6, integrating both radar and photometric observations. Begin developing Python scripts to automate and streamline the shape modeling workflow. In parallel, continue TRAPPIST scheduling and observations and compile relevant archival photometric data to initiate convex modeling for additional targets in preparation for future radar modeling. Extend the analysis of 2002 KL6 by incorporating polarimetric and thermal infrared data to investigate surface properties and assess the presence of the YORP effect, and submit the paper for publication. Two months visit to the Florida Space Institute to meet the Arecibo radar team.

**Year 2 (2026 – 2027):** Continue TRAPPIST observations and data reduction, with the goal of determining convex and radar based shape models for approximately 12 NEA targets. In parallel, I will advance the development of automated scripts to streamline the modeling workflow and enhance the functionality of the SHAPE software. Visit to one of the TRAPPIST observatory sites to gain hands-on experience with the telescope system and its operations. Submit a paper with the best targets models.

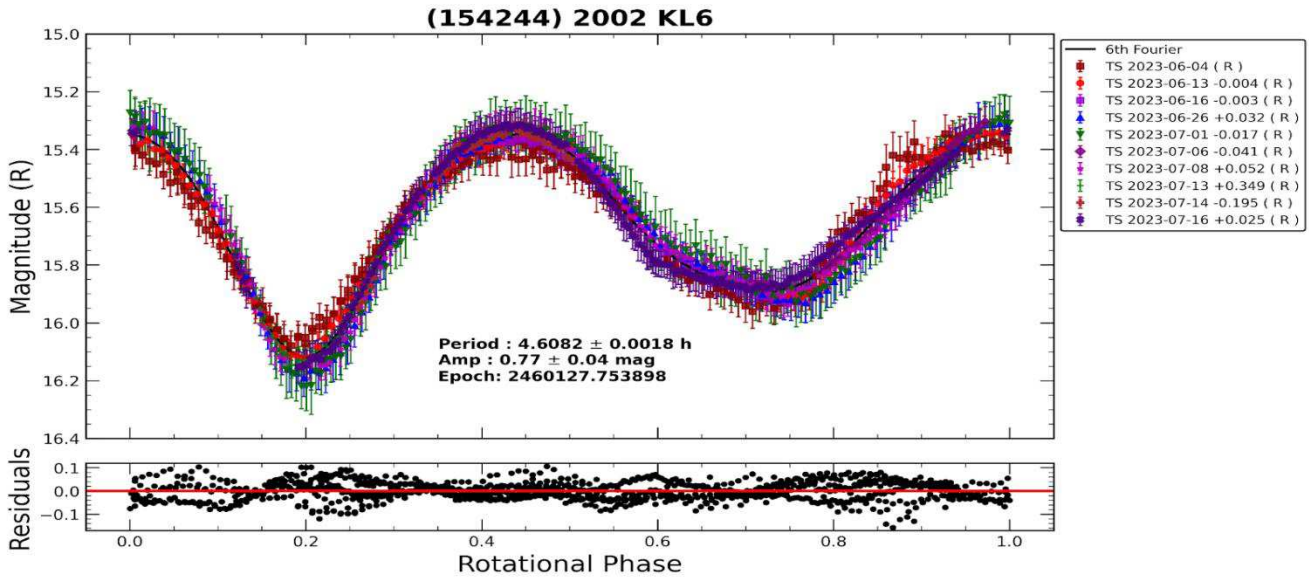
**Year 3 (2027 – 2028):** In this year, I will continue TRAPPIST observations to support and expand our ongoing shape modeling campaign. The focus will be on integrating radar data with existing convex shape models to refine and enhance the 3D models for approximately 8 more NEA targets. This phase builds on previous efforts and represents a continuation of our work to improve the accuracy of shape and spin state determinations. As the number of modeled asteroids increases, we will initiate a systematic statistical analysis of the sample to investigate trends in morphology, spin properties and YORP effects. Moreover, I plan to visit again the UCF radar group for a short stay to learn and discuss the preliminary results.

**Year 4 (2028 – 2029):** Finalize TRAPPIST observations and complete shape modeling for the remaining targets, focusing on the last NEA requiring combined convex and radar based models. Conclude the statistical analysis of the full sample of shape models to extract key trends in morphology, spin properties, and YORP. Prepare and submit a summary publication presenting the results, methodology, and scientific implications of the project. Write the manuscript, submit and defend my thesis.

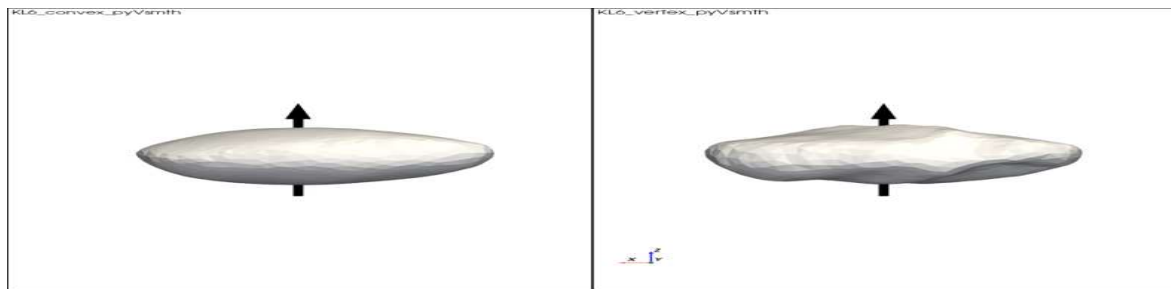
## Figures and Tables:

Number	Name / Designation	Arecibo	TRAPPIST	2026	2027	2028	2029
3752	Camillo	2013-2018			Jul 28 - Sep 26	Feb 06 - Mar 29	
1685	Toro	1980-1988-2012	Y	Apr 03 - Jun 07		May 07 - Dec 31	Jan 01 - May 10
7341	1991 VK	2007-2012-2017		Sep 30 - Dec 29	Feb 03 - Apr 16		
152664	1998 FW4	2009-2013					Sep 14 - Oct 01
52760	1998 ML14	1998-2013				Jun 25 - Jul 30	
33342	1998 WT24	2001-2015		Dec 04 - Dec 22			Nov 04 - Nov 27
159402	1999 AP10	2009	Y				
137924	2000 BD19	2007					Jan 27 - Feb 16
68267	2001 EA16	2014			Oct 07 - Oct 25		
285944	2001 RZ11	2014			Jul 25 - Sep 02		Dec 04 - Dec 31
337866	2001 WL15	2016					Dec 04 - Dec 31
68950	2002 QF15	2006-2016-2019				Sep 23 - Oct 29	
163696	2003 EB50	2015	Y		May 05 - Jun 13		May 11 - Jun 02
215588	2003 HF2	2017			Jul 06 - Jul 16		
413260	2003 TL4	2016					Oct 08 - Oct 30
144411	2004 EW9	2020				Apr 07 - Jun 03	
164400	2005 GN59	2008		Jan 02 - Mar 04			
308242	2005 GO21	2012-2014			May 14 - Jul 19		May 05 - Jun 12
242708	2005 UK1	2014		Jan 01 - Jan 11			Dec 09 - Dec 25
	2006 NL	2020	Y				
	2017 VR12	2018	Y				

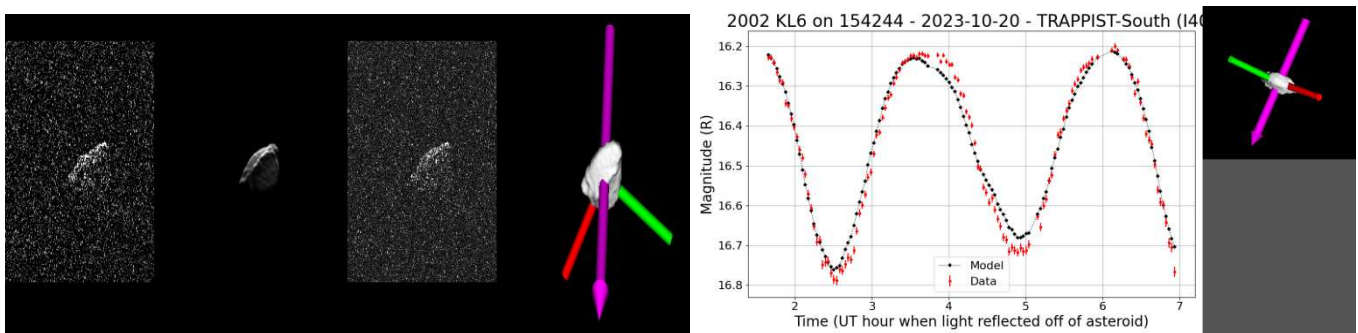
**Table1:** Table of 21 NEAs observed with the Arecibo Observatory and already observed with TRAPPIST, or observable between 2026 and 2029. The visibility windows are defined as visible from either TRAPPIST telescope, at apparent magnitude  $V < 17$  mag, and for more than 2 hours per night.



**Figure1:** Phased light curve of 2002 KL6 obtained with TRAPPIST-North (TN) and -South (TS) during the 2023 apparition at ten different epochs. This figure demonstrates the capability of TRAPPIST to produce precise and densely sampled light curves thanks to the large amount of time available, the large sky coverage in both hemispheres and the high quality of the sites (Miftah et al., in prep).



**Figure2 :** Shape model of NEA (154244) 2002 KL6. *Left:* Convex shape model derived from the optical light curve inversion method, scaled to a diameter of 0.7 km. *Right:* Refined shape model generated by combining photometric and radar observations using a vertex modeling approach, with the previously derived convex model used as the initial input (Miftah et al., in prep).



**Figure3 :** *Upper left.* Delay-Doppler radar images from the Arecibo Observatory, overlaid with the synthetic delay-Doppler projection of the best-fit shape model (computed via SHAPE software). *Upper right.* Example optical light curve compared against the synthetic light curve generated from the combined radar-photometric shape, showing excellent agreement. *Lower panel.* Continuous wave (CW) radar spectra from AO plotted alongside spectra predicted by the vertex-based model from SHAPE, again highlighting a close match (Miftah et al., in prep).

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- +**Mathias, Donovan L., Lorian F. Wheeler, and Jessie L. Dotson.** "A probabilistic asteroid impact risk model: assessment of sub-300 m impacts." *Icarus* 289 (2017): 106-119.
- +**Rivkin, Andrew S., et al.** "The double asteroid redirection test (DART): Planetary defense investigations and requirements." *The Planetary Science Journal* 2.5 (2021): 173.
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- +**Kaasalainen, Mikko, Johanna Torppa, and Karri Muinonen.** "Optimization methods for asteroid lightcurve inversion: II. The complete inverse problem." *Icarus* 153.1 (2001): 37-51.
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- +**Ferrais, M., et al.** "Photometric Monitoring of NEAs Observed in Radar." *Asteroids, Comets, Meteors Conference*. Vol. 2851. 20
- +**Miftah, M. A., et al.** "Rotation Periods of Five Near-Earth Asteroids with the Trappist Telescopes:(17188) 1999 WC2,(242450) 2004 QY2,(503871) 2000 SL, 2023 DZ2 And 2023 CM." *Minor Planet Bulletin* 51 (2024).

## **2. COMMENTS ON CHANGES MADE IN THE RESEARCH PROJECT IN CASE OF RESUBMISSION (OPTIONAL)**

*In case of former application submitted to the F.R.S.-FNRS via the same funding instrument, please specify the main changes made in your funding application following previous submission, identifying comments from experts that you may have taken into account (max. 1 page).*

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## **3. ACTIVITIES REPORT ON THE FIRST YEAR OF DOCTORATE**

**ONLY FOR “1<sup>ST</sup> GRANT - 2<sup>ND</sup> YEAR”**

*Please write a brief report (max. 2 pages) underlining the progress of your research during the first year of your doctorate.*

## **4. POTENTIAL INTERDISCIPLINARY APPROACH OF THE RESEARCH PROJECT (OPTIONAL)**

*If applicable, please identify the interdisciplinary approach of your research project (max. 1 page).*

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## 5. DESCRIPTION OF THE WORK ENVIRONMENT

*Please provide the information accounting for the adequacy of the environment (available intellectual and/or material means) to carry out the research as detailed in the submitted project. Please specify the assets of the research environment related to the project and the main publications of the laboratory/promoter (max. 1 page).*

My PhD thesis is carried out within the “COMetsMETeors& Asteroids (COMETA)” research group of the Space Sciences, Technologies & Astrophysics Research (STAR) Institute of the University of Liège (ULiège). The team is led by prof. Emmanuel Jehin (FNRS Research Director), and includes 4 PhD and 1 post-doc. The group is very active in the field of the small bodies of the solar system and it is internationally recognized for the quality of its work with a large asset of collaborators. The STAR Institute of ULiège hosts more than one hundred researchers who conduct cutting edge research focused on planetology, stellar physics, extragalactic and particle astrophysics, and instrumentation and many resources are available. In the COMETA group we also have an IT support that helps us for matters related to computers and installation of software as well as providing help for programming. I have already been able to enjoy all these possibilities and help during my master thesis.

The data for this project will come mostly from two facilities. First our two TRAPPIST robotic telescopes, located in both hemispheres and to which we have unlimited access to collect the photometric measurements of the 21 new targets during the next 4 years. TRAPPIST-South is a 60-cm robotic telescope that was installed at the ESO La Silla Observatory. It is funded mostly by the Belgian F.R.S.-FNRS and the STAR Institute of ULiège. The telescope is exclusively devoted to the detection and characterization by the transit technique of exoplanets (50%) and to the study of comets and other small bodies in the Solar system (50%). In 2015 a twin telescope was funded by ULiège to have access to the northern hemisphere. It was installed at the Oukaimeden Observatory of the University of Cadi Ayyad in the Atlas Mountains of Morocco and fostered since then a very successful program between the two universities with already three PhD projects completed as well as several master thesis from both countries. This is why we propose this thesis as a co-tutelle with prof. Jabiri on the Moroccan side. With about 300 clear nights per year on both sides it allows to collect a lot of long photometric series. These telescope are operated by the COMETA group I belong.

The other data are coming from the unique Arecibo Observatory archive which has accumulated hundreds of radar images of NEAs. Unfortunately Arecibo is not operational anymore but we have access to this large dataset thanks to a collaboration with the radar team of the Florida Space Institute at UCF (see letter of support from its director). Several visits are planned there during my thesis.

TRAPPIST project: <https://www.trappist.uliege.be/>

COMETA group webpage: <https://www.cometa.uliege.be/>

Florida Space Institute: <https://fsi.ucf.edu/>



## 6. SUMMARY OF THE MASTER'S THESIS OR EQUIVALENT

*Please provide a summary of your master's thesis or any equivalent, even if you have not graduated yet (max. 1 page).*

### **Analysis of asteroid light curves using the TRAPPIST telescopes**

My Master's thesis project, entitled "Analysis of Asteroid Light Curves Using the TRAPPIST Telescopes" supervised by Prof. Emmanuel Jehin, focused on the observation of seven asteroids, six of which were NEAs, with the goal of determining their light curves, rotation periods, amplitudes, and BVRI color indices. These parameters are essential for deriving their convex shape models and estimating their spectral classifications. The project was structured into three main parts. In the first part, I provided an overview of asteroids and the techniques I used to study them, with particular emphasis on those relevant to my project. This section established the scientific context and laid the groundwork for the observational work. The second part focused on the planning and execution of the observations. I scheduled observations based on the visibility windows and scientific priority of each target for both TRAPPIST-North in Morocco and TRAPPIST-South in Chile. After selecting the observation windows, I prepared detailed observing plans required by the telescopes for tracking the asteroids. The raw images collected were then processed through standard reduction procedures, including bias and dark subtraction and flat field division, using a Python script. Once reduced, I performed aperture photometry using the Mommert Photometry Pipeline to extract the instrumental magnitude of the asteroids, and calibrate the measurements by matching reference stars using the Pan-STARRS catalog. With the calibrated magnitudes, I used the Peranso software, applying both FALC and ANOVA methods to determine and refine the rotation periods, which were then used to phase the light curves. In the final part of the master thesis, I presented the results obtained for all seven asteroids. For five of them, I was able to determine both the rotation period and the amplitude, and the color indices for only (503871) 2000 SL which yielded an S-type asteroid. The remaining two, (3122) Florence and (5549) Bobstefanik could not be fully analyzed due to insufficient data from their 2023 apparition. Among the successfully analyzed targets, 2023DZ2 and 2023CM were newly discovered in 2023 during close approaches to Earth. I successfully determined their rotation periods and amplitudes, which matched published results. Additionally, (503871)2000SL and (242540) 2004QY2 were analyzed for the first time, as no prior results existed for them. The final object, (17188) 1999WC2, showed a rotation period consistent with previous studies. Thanks to the high quality of the measurements and the novelty of the findings, the results for the five NEAs, (17188) 1999 WC2, (242540) 2004 QY2, (503871) 2000 SL, 2023 DZ2, and 2023 CM, were published in the Minor Planet Bulletin (Miftah et al. 2024) and data made publicly available in the Asteroid Light curve Database (ALCDEF) for use in future research.

## 7. ADDITIONAL COMMENTS (OPTIONAL)

*If you want to communicate elements that have not been mentioned elsewhere in the file, please provide this information below in max. 2 pages.*

*Please note that in case the presented project provides for the involvement of patients and/or human or animal subjects, it is important that the project includes justifications on the planned sample size (number of subjects included in the study/studies) and how the size is relevant (based on statistical power calculations, for instance). It is also important to explain how the number of patients/subjects expected can be reached. In case the project provides for the involvement of patients and/or subjects, please provide those pieces of information under this section (if not already mentioned elsewhere in the project). Ultimately, this information (or the lack of information) may be taken into account by experts in the frame of the evaluation of your funding application.*

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## 8. **PH.D. WORK CALENDAR PER MONTH**

*Please provide a calendar on a monthly basis for your Ph.D. works planned for the next 3 years (1<sup>st</sup> grant - 2<sup>nd</sup> year) or 4 years (1<sup>st</sup> grant - 1<sup>st</sup> year) (max. 2 pages).*

### **Monthly calendar:**

- **WP1:**

- a) (154244) 2002 KL6 work completion and publication
- b) TRAPPIST observations
- c) SHAPE automation, Python scripts for setup files, pole searches, smearing
- d) Visit the UCF radar group in USA for a short stay
- e) Participation in the 15<sup>th</sup> ACM 2025 conference in Poznan, Poland
- f) Participation in the EPSC 2026 conference in Netherlands

- **WP2:**

- a) Continue TRAPPIST observations
- b) Convex and radar shape models (~ 12 targets)
- c) Publication of the results for the best models
- d) Visit one of TRAPPIST sites
- e) Participation in the EPSC 2027 conference in Toulouse, France

- **WP3 :**

- a) Convex and radar shape models (~8 targets)
- b) Continue with the TRAPPIST observations
- c) Initiate a statistical analysis of the preliminary results
- d) Publication of the results for the 8 targets
- e) Participate in a mission to the Oukaimeden Observatory to support ULiège master's students in their work on asteroids, assisting with preparation, observations, and data analysis
- f) Participation in the EPSC conference 2028

- **WP4:**

- a) Complete the TRAPPIST observations
- b) Completion of final convex and radar models
- c) Completion of the statistical analysis
- d) Publication of the summary paper
- e) Participate in a mission to the Oukaimeden Observatory to support ULiège master's students in their work on asteroids, assisting with preparation, observations, and data analysis
- f) Thesis writing and submission for defense



WORK PLAN											
OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT
YEAR 1 (2025-2026)											
a				d					e		f
b + c											
YEAR 2 (2026-2027)											
					d						e
a + b + c											
YEAR 3 (2027-2028)											
					e						f
a + b + c + d											
YEAR 4 (2028-2029)											
a + b + c + d											
					e			f			

# Publications and communications of Mohamed Amine Miftah

*This publications list contains only articles that comply with the OA decree of the FWB.*

Seligman, D. Z., Micheli, M., Farnocchia, D., Denneau, L., Noonan, J. W., Hsieh, H. H., Santana-Ros, T., Tonry, J., Auchettl, K., Conversi, L., Devogèle, M., Faggioli, L., Feinstein, A. D., Fenucci, M., Ferrais, M., Frincke, T., Gillon, M., Hainaut, O. R., Hart, K., ... Zhang, Q. (01 August 2025). Discovery and Preliminary Characterization of a Third Interstellar Object: 3I/ATLAS. *Astrophysical Journal*, 989, 36. doi:10.3847/2041-8213/adf49a  
<https://hdl.handle.net/2268/335360>

Choukroun, A., Marciniak, A., Ďurech, J., Perla, J., Ogłóza, W., Szakáts, R., Molnár, L., Pál, A., Monteiro, F., Mieczkowska, I., Beisker, W., Agnetti, D., Anderson, C., Andersson, S., Antusiewicz, D., Arcoverde, P., Aubry, R.-L., Bacci, P., Bacci, R., ... Żukowski, K. (01 June 2025). Asteroid sizes determined with thermophysical model and stellar occultations. *Astronomy and Astrophysics*, 698, 298. doi:10.1051/0004-6361/202554476  
<https://hdl.handle.net/2268/334161>

Miftah, M. A., Ferrais, M., Moulane, Y., Jehin, E., Jabiri, A., & Benkhaldoun, Z. (01 January 2024). Rotation Periods of Five Near-Earth Asteroids with the Trappist Telescopes: (17188) 1999 WC2, (242450) 2004 QY2, (503871) 2000 SL, 2023 DZ2 And 2023 CM. *Minor Planet Bulletin*, 51, 76-78.  
<https://hdl.handle.net/2268/312685>

## RÉSULTATS ACADÉMIQUES ET CLASSEMENT, TOUTES SPECIALITÉS CONFONDUES

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Nom et prénom de la candidate ou du candidat / Full name of the applicant	Mohamed Amine MIFTAH
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Cycle(s) précédant le doctorat <i>Cycle before postgraduate</i>	# années effectives suivies pour obtenir le diplôme / # années théoriques prévues dans le cycle <i>#effective years for obtaining the degree / # years theoretically provided for in the degree cycle</i> Ex / e.g.: 5/4	Mention ou % obtenu <i>Honours/classification or % obtained</i>
Master ou équivalent <sup>1</sup> / <i>Master or equivalent</i>	2/2	Bien
Bachelier / <i>Undergraduate</i>	3/3	Passable

Classement de la candidate ou du candidat concernant le diplôme de Master ou équivalent par rapport au nombre de candidat e s en fin de cycle / Master or equivalent ranking of the applicant out of the number of students to be graduated.

1/20

Mémoire de Master : mention ou % obtenu / Master's thesis: Honours/classification or % obtained.

Pour les étudiant e s devant encore terminer le cycle, indiquez « en cours » / For students who have not finished yet, indicate "In progress".

16/20

Date  
9 août 2025

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<sup>1</sup> Pour les candidates et candidats n'ayant pas encore terminé leur cursus, il y a lieu de joindre un relevé de notes des examens présentés dans le cadre du Master. / Applicants currently in pursuit of their degree must submit a copy of their Master degree transcript listing the exams taken and marks/grades awarded.

<sup>2</sup> Ce document n'est pas valable sans le cachet de la Faculté. / The document is invalid if the seal of the Faculty is missing.



Liège, le 9 décembre 2024.

### Attestation d'inscription

La Rectrice de l'Université de Liège certifie que :

**Mohamed Amine Miftah**

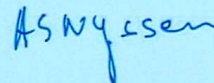
matricule : **202408677**

**né le 05/01/2001 à Menera-Marrakech (Maroc)**

a été régulièrement inscrit pour les années académiques suivantes :

**2024-2025    Formation doctorale en sciences (sciences spatiales)**  
**Doctorat en sciences (sciences spatiales)**

La Rectrice





116741

Vu la loi n° 01-00 portant organisation de l'enseignement supérieur promulguée par le dahir n° 1-00-199 du 15 safar 1421 (19 mai 2000) notamment son article 3 :

Vu le décret n° 2.13.841 du 11 rabia I 1435 (13 janvier 2014), modifiant et complétant le décret n° 2-04-89 du 18 rabii II 1425 (7 juin 2004) fixant la vocation des établissements universitaires, les cycles des études supérieures ainsi que les diplômes nationaux correspondants.

Vu l'arrêté du Ministère de l'Enseignement Supérieur, de la Recherche Scientifique et de la Formation des Cadres n° 2083.14 du 5 Di Elhijja 1435 (30 septembre 2014) approuvant le cahier des normes pédagogiques nationales du cycle de master ;  
Vu le procès-verbal de la commission des délibérations du : 24/07/2023

Le Président de l'Université Cadi Ayyad atteste

que : **MOHAMED AMINE MIFTAH**

Né le : **05 janvier 2001 à MARRAKECH**

N° Carte d'identité nationale : **EE921874**

CNE : **G139828298**

a obtenu le **MASTER**

Filière : **Physique des Hautes Energies, Astronomie et Physique Computationnelle**  
Parcours: **Astrophysique**

Mention : **Bien**

Le Président  
الرئيس

Marrakech le : 08 Novembre 2023  
مراكش في : 08 نوفمبر 2023

Le Doyen  
العبد

الماستر  
Master

بناء على القانون 01.00 المتعلق بتنظيم التعليم العالي الصادر بتنفيذ الظهير الشريف رقم 19.1421.15 مور 15 سبتمبر 2000 ولا سيما المادة 3  
وعلى المرسوم رقم 2.13.841 الصادر في 11 ربيع الأول 1435 (13 يناير 2014) بتغيير وتتميم المرسوم رقم 2.04.89 بتاريخ 18 ربيع الثاني 1425 (7 يونيو 2004) لتحديد التخصصات المؤهلة للإمتحانات الوطنية وإحداث الشهادات الوطنية الملقية؛  
وعلى قرار وزير التعليم العالي والبحث العلمي وتكوين الأطر رقم 2083.14 صادر في 5 ذى الحجة 1435 (30 سبتمبر 2014) بالمصادقة على نقر الضوابط  
و بعد الإطلاع على محضر لجنة الدراسات بتاريخ : 2023/07/24

يشهد رئيس جامعة القاضي عياشي  
أن : **محمد امين مفتاح**

المزاول في : **05 يناير 2001** بمراكش

رقم بطاقة التعريف الوطنية : **EE921874**

الرقم الوطني للطلاب : **G139828298**

أحرز على **الماستر**

مسلك : **فيزياء الطاقات العالية، علم الفلك والفيزياء الحسابية**

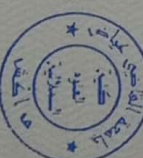
مسار : **الفيزياء الفلكية**

بمجرد : **حسن**

الرئيس  
بالحيد بوك دوير



العبد  
المودن الحسن



رقم : 2023/202206881 N°

تنبيه : نعلم هذه الشهادة غير ملزمة، ويمكن عند الحاجة سحبها والصادقة عليها من طرف السلطات المختصة