ÉCOLE NORMALE SUPÉRIEURE DE LYON

Lab PHYS ENS de LYON

Offre de thèse – *PhD proposal*
Aérodynamique du vol de papillons en gravité altérée
Butterfly flight aerodynamics in altered gravity

Financement : CNES - (date limite de candidature le 16/03/2023) : https://recrutement.cnes.fr/en/annonce/2035541-23-130-butterfly-flight-aerodynamics-in-altered-gravity-69007-lyon
Direction de thèse : Mickaël BOURGOIN (DR CNRS) et Nicolas PLIHON (DR CNRS)

La thèse, co-financée par le CNES, vise à fournir une caractérisation expérimentale détaillée du vol de papillons en micro et hyper-gravité, de sorte à étudier l'évolution des caractéristiques du vol battu et élucider les couplages aérodynamiques à l'origine de la poussée et de la portance en fonction du niveau de gravité. Pour cela, des expériences en table tournante et en vol parabolique seront effectuées.
Le candidat ou la candidate idéal(e) doit avoir une bonne formation académique en mécanique des fluides, en aérodynamique ou en physique et le goût des expériences fines et de l'analyse d'images (obligatoire pour la reconstruction haute résolution du motif de battement d'aile et de la trajectoire du papillon). D'excellentes capacités de communication (écrite, lue, orale), l'autonomie, la curiosité, notamment interdisciplinaire, et la capacité à travailler en équipe sont indispensables.
Pour tout complément d'information, n'hésitez pas à prendre contact avec Mickael Bourgoin (mickael.bourgoin@ens-lyon.fr), Nicolas Plihon (nicolas.plihon@ens-lyon.fr) et/ou Ariane Gayout (a.m.m.gayout@rug.nl).

A thesis offer is available in our group, at the Physics Laboratory of the ENS of Lyon, on the Aerodynamics of butterfly flight in altered gravity.
The thesis, co-financed by the CNES, aims at providing a detailed experimental characterization of the flight of butterflies in micro and hyper-gravity, in order to study the evolution of the characteristics of the flapping flight and to elucidate the aerodynamic couplings at the origin of the thrust and the lift as a function of the gravity level. For that, experiments in turntable and parabolic flight will be performed.
The details of the project, as well as the application form, are available via the following link (application deadline 16/03/2023):
https://recrutement.cnes.fr/en/annonce/2035541-23-130-butterfly-flight-aerodynamics-in-altered-gravity-69007-lyon
The ideal candidate should have a good academic background in fluid mechanics and/or aerodynamics, and a taste for fine experiments and image analysis (mandatory for the high resolution reconstruction of the flapping pattern and the butterfly trajectory). Expertise in particle tracking velocimetry (PTV) or particle imaging velocimetry (PIV) may be of interest but can in any case be acquired during the thesis. Excellent communication skills (written, read, oral), autonomy, curiosity and ability to work in a team are essential.
For further information, please contact Mickaël Bourgoin (mickael.bourgoin@ens-lyon.fr), Nicolas Plihon (nicolas.plihon@ens-lyon.fr) and/or Ariane Gayout (a.m.m.gayout@rug.nl).

Detailed scientific project

When flapping their wings, butterflies generate vortices around them that are producing both the thrust they need to advance and the lift needed not to fall, compensating gravity. PHOeBUS is a scientific project, by a consortium of physicists and entomologists whose initial phase has been supported by the French Space Agency (CNES) in views of parabolic flights, and whose aim is to understand this subtle aerodynamic coupling by its modification in altered gravity.

In the absence of gravity for instance, flapping its wings as if on Earth, the butterfly would produce the same lift, which however would induce a vertical bias to its trajectory. Exploring the capability of butterflies to adjust their flapping motion and adapt to various gravity levels is a way of understanding both fundamental aerodynamics and behavioral response from the butterflies and develop new bio-inspired strategies for future innovations in Aeronautics and Unmanned Aerial Vehicules.

Figure 1: Flapping motion of a butterfly with its generated vortices (*Fuchiwaki et al.* 2013)

The goal of this PhD project is to provide a detailed experimental characterization of butterflies' flights in altered gravity, and to provide the evolutions of the flapping flight characteristics (flapping frequency and amplitude, relative position of the wings relative to the body, orientation of the body relative to gravity and butterfly trajectory, etc…) as a function of the level of gravity. Two conditions will be explored during this PhD:

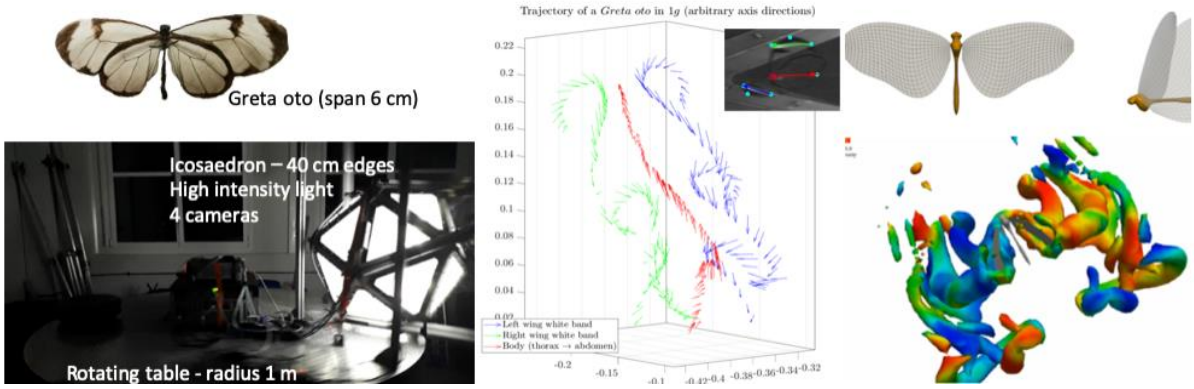
- hyper gravity conditions, on a rotating table available at the Laboratoire de Physique (ENS de Lyon) where the effect of centrifugal forces result in an effective-gravity higher than unity.
- parabolic flight campaigns for both micro-gravity and hyper-gravity periods.

During these experiments, the trajectory and flapping pattern of the butterflies will be recorded using a camera network ensuring stereoscopic 3D reconstruction with great temporal resolution. This requires a setup using multiple synchronized cameras. Lighting is also essential in the experiment, as it is central for the image quality and may also be used as a flight trigger to the butterflies. Preliminary tests on the rotating table using 4 cameras and dedicated illumination were conducted at the ENS de Lyon in spring 2022 and allowed to reconstruct the flapping pattern of Greta oto (a tropical species identified as an ideal candidate with our entomological colleagues) – see Fig. 2. From these mesaurements, numerical simulations of the flow field generated by the reconstructed flapping pattern were conducted in collaboration with the group of Pr Liu at Chiba U. (Japan).

The work plan of the PhD project will be the following

- Experimental campaigns on the turn-table (year 1). Following an upgrade of the experimental setup (currently shown in Fig. 2), the PhD candidate will identify strategies to trigger the flight of butterflies on demand. Extensive experimental campaigns on several butterfly species will be carried out for increasing values of the effective gravity (we have an all-year-long provider of tropical species). The video will be analyzed using modern tracking methods (including AI) to provide statistics on flapping pattern dependence with gravity.
- First experimental campaigns on parabolic flights (year 2). The experimental setup will be adapted to the constraints of parabolic flights, and a complete data-set will be derived from this study.

- Measurements of flow field generated by butterflies (year 3). Advanced optical velocimetry techniques will be adapted to study the flow field (and in particular the vorticity field) generated by butterflies in both hyper and micro gravity. This data set will be compared to numerical simulations led at Chiba University.



If time allows, advanced topics such as wing deformation, extension of the imaging technique to dragonflies will be addressed during the third year of the PhD thesis. Strategies of adaptation implemented by butterflies in the presence of altered gravity will also be analysed in collaboration with robotic experts in insect behaviour in Marseille, and tailored to UAV strategies.

This project is developed in collaboration with entomologists at the Museum National d'Histoire Naturelle, the group of Pr Liu at Chiba U. (expert in CFD) and roboticists in Marseille and Nancy, and experts in birds and insects flights at U. Groningen (Netherlands). Note that there are no regulations for experimentations using insects.

The ideal candidate must have a good academic background in fluid mechanics and/or aerodynamics, and the taste for fine experiments and image analysis (mandatory for the high-resolution reconstruction of flapping pattern and butterfly trajectory). Experience with Particle Tracking Velocimetry or Particle Image Velocimetry may be interesting but can in any case be acquired during the thesis. Excellent communication skills (written, read, spoken), autonomy, curiosity and ability to work in a team are mandatory.

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