PhD Thesis Proposal

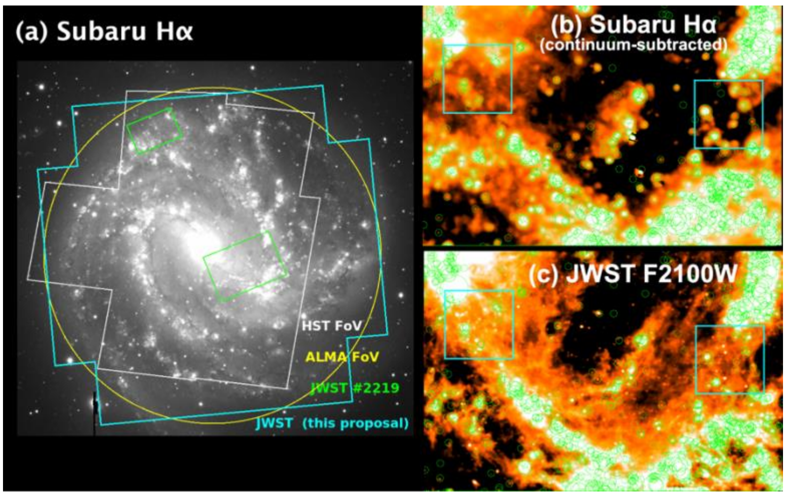
Titre : Probing the embedded-to-exposed star formation sequence across the barred spiral galaxy M83 with JWST and multi-wavelength data.

Keywords: star formation, gas accretion, gas ejection, galaxy evolution, galactic bars, collisional rings, numerical simulations

Project Summary (4000 characters)

Observations of high-redshift galaxies reveal that stars were already forming when the Universe was still very young, raising fundamental questions about the role of galactic dynamics—spiral arms, bars, density waves—in triggering this activity. In dense molecular clouds, young stars remain embedded within dusty cocoons that obscure their optical emission. Only after nuclear reactions ignite and the surrounding gas becomes ionized do Hα-emitting regions become visible. Prior to this phase, infrared emission at 21 µm provides a privileged tracer of the youngest objects. Our understanding of these evolutionary stages still relies heavily on studies of the Milky Way and a handful of nearby galaxies.

The project aims to investigate these processes in the barred spiral galaxy M83, a close analogue of the Milky Way located less than 5 Mpc away. M83 will be fully mapped with the James Webb Space Telescope in the mid-infrared through a mosaic to be obtained with the MIRI instrument at 21 µm, scheduled for summer 2026. These observations, combined with an exceptional multi-wavelength dataset (ALMA, Subaru, HST, VLA, GBT), will provide a unique laboratory for linking molecular clouds, galactic dynamics, and star-forming regions. The JWST data will enable the identification of the earliest evolutionary phases (O–B2 types), well before they become visible in Hα, while the other datasets will characterize the physical and dynamical environment of the regions under study.



Galaxy M83. a. Field of view of the JWST observations at 21 µm, together with the ALMA and HST data. The green rectangle marks the region already available in the archives. Zoom on the green rectangle: Hα emission (**b**, Subaru) and 21 µm emission (**c**, JWST).

This project is fully aligned with the priorities of the Île-de-France Space Academy: the exploitation of cutting-edge space-based observations, the processing of large and complex datasets, multi-wavelength interpretation, and physical modelling. The analysis of the 36 JWST/MIRI pointings will provide a valuable training opportunity for a PhD student, strengthening the JWST expertise within the Paris region and contributing to the development of young researchers capable of extracting scientific value from complex space-mission data. The doctoral project will build skills directly applicable to careers in the space sector, including the analysis of space-borne datasets, mastery of data-processing pipelines, advanced astrophysical interpretation, and numerical modelling.

The scientific positioning of the project is strong: M83 is closer and more comprehensively observed than the spiral galaxies of the PHANGS program, and the international collaboration with Prof. Jin Koda (Stony Brook University) ensures privileged access to both data and expertise. The dataset covering the entire galaxy is unique and will make it possible to investigate star-formation mechanisms on galactic scales with unprecedented precision.

The PhD program will include: (1) the systematic identification of young sources detected at 21 µm; (2) the analysis of their galactic environment (spiral arms, bar, gas density); (3) the determination of the triggering mechanisms, whether dynamical or linked to supernovae; and (4) the comparison of observations with RAMSES hydrodynamical simulations. In particular, the 21 cm radio maps will make it possible to test the impact of supernovae through their synchrotron emission.

The project is expected to lead to several publications in international journals and presentations at major conferences. The PhD student will benefit from the laboratory's resources (LUX), including computing infrastructure, documentation, and a supportive research environment. A co-tutelle with Stony Brook University in New York is also a possibility.

Acronyms:

ALMA: Atacama Large Millimeter Array, Chile; HST: Hubble Space Telescope; GBT: Green Bank Telescope, USA; PHANGS: *Physics at High Angular resolution in Nearby GalaxieS* (international collaboration); Subaru: 8.2-m telescope, Mauna Kea Observatory; VLA: Very Large Array (New Mexico)

Topic:
Early star formation in nearby galaxies using JWST/MIRI data and multi-wavelength observations.

Research Area :
Extragalactic astrophysics — star formation and the evolution of nearby galaxies.

Objectives:

Identify the earliest phases of star formation in the galaxy M83 using JWST/MIRI observations at 21 µm, which are sensitive to very young objects still embedded in their dusty cocoons.

Link these young sources to their galactic environment (spiral arms, bar, molecular and atomic gas density) in order to understand how galactic dynamics influences the triggering of star formation.

Compare different multi-wavelength tracers (JWST, ALMA, HST, Subaru, VLA, GBT) to characterize the local physical conditions and the mechanisms driving the evolution of star-forming regions.

Test triggering scenarios— dynamic gas compression or the impact of supernovae—by confronting the observations with 21 cm radio maps and RAMSES hydrodynamical simulations.

Produce a comprehensive, galaxy-wide analysis, that clarifies the links between molecular clouds, internal dynamics, and star formation in a galaxy analogous to the Milky Way.

Scientific Context:
Studies of high-redshift galaxies show that stars were already forming when the Universe was still very young, raising fundamental questions about star-formation mechanisms and their connection to galactic dynamics (spiral arms, density waves). In dense, dusty molecular clouds, young stars remain embedded in cocoons that obscure their optical emission. Once nuclear reactions ignite, the surrounding gas becomes ionized, the cocoon disperses, and the Hα-emitting region becomes visible. Prior to this stage, 21 µm infrared emission reveals the youngest objects. Our understanding of these processes still relies primarily on the Milky Way and a few nearby galaxies.

Method:
The study will be based on the analysis of JWST/MIRI observations at 21 µm to identify young stellar objects in M83. These sources will be compared with multi-wavelength datasets (ALMA, HST, Subaru, VLA, GBT) to characterize their environment and evolutionary stage. A spatial analysis will assess their connection to galactic dynamics (spiral arms, bar, gas density). Triggering scenarios—dynamic compression or the influence of supernovae—will be tested using 21 cm radio maps and confronted with RAMSES hydrodynamical simulations. The project will combine image processing, statistical analysis, and numerical modelling.

Expected results:
The project is expected to produce a complete and homogeneous map of the early phases of star formation in the galaxy M83, systematically identifying young sources detected at 21 µm. The multi-wavelength analysis will characterize their physical and dynamical environment and determine under which conditions star formation is triggered. Comparisons with radio maps and hydrodynamical simulations should help discriminate between the dominant mechanisms—dynamic gas compression or the influence of supernovae. Altogether, the project will provide a coherent view of star-formation processes on galactic scales, leading to several publications in international journals and presentations at major conferences.

Bibliography:
Boquien & Salim 2021, A&A, 653, A149
Calzetti et al. 2025, ApJ, 991, 27
Della Bruna et al. 2022. A&A, 666, A29
Dobbs & Baba 2014, PASA, 31, 35
Eibensteiner et al. 2023, A&A, 675, A37
Hernandez et al. 2020, MNRAS, 493, 2872
Hirota et al. 2024, ApJ, 976, 198
Kawamura et al. 2009, ApJS 184, 1

Kim et al. 2022, MNRAS, 516, 3006
Koda et al. 2023, ApJ, 949,108
Koda et al. 2025, ApJ, 986, 29
Lee et al. 2024, ApJ, 968, 97
Pedrini et al. 2025, ApJ, 992, 96
Rosolowsky et al. 2021, MNRAS, 502, 1218
Sextl et al. 2025, ApJ, 987, 138
Wang et al. 2021, MNRAS, 508, 6155

Material, Scientific (including Safety), and Financial Conditions of the Research Project

The student will benefit from the standard material and logistical resources provided within LUX, including access to computing infrastructure, documentation resources, workspace, and all tools required to carry out the doctoral project.

International Dimension

Jin Koda (Stony Brook Univ., NY, USA)

Planned Collaborations

Jin Koda (Stony Brook Univ., NY, USA)

Dissemination, Publication, and Intellectual Property Objectives

The project is expected to lead to several peer-reviewed publications and presentations at major international conferences, ensuring strong visibility within the astrophysics and space-science communities. Issues related to dissemination, confidentiality, and intellectual property will be handled in accordance with institutional guidelines.

Supervisors (name, email, phone)

Anne-Laure Melchior (Anne-Laure.Melchior@obspm.fr) -- 01 40 51 20 61
Françoise Combes (Francoise.Combes@obspm.fr) -- 01 40 51 20 77

Host Laboratory

UMR-8262 LUX
Laboratoire d’étude de l’Univers et des phénomènes eXtrêmes
77, avenue Denfert-Rochereau 75014 Paris

Candidate Profile and Required Skills

The candidate should have a strong background in physics and astrophysics, with a clear interest in galaxy evolution and star formation. Good proficiency in programming languages (e.g., Python) and scientific tools is expected. Experience in data analysis—particularly the processing and interpretation of astronomical images—and/or skills in statistics, numerical modelling, or hydrodynamical simulations will be considered an asset. The project also requires rigor, autonomy, the ability to work collaboratively in an international environment, and strong written and oral communication skills.