Thesis subject

Name of the laboratory: Laboratoire d'Astrophysique de Marseille

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Subject's title: Detecting and Classifying planetary transits with the PLATO mission data.

Subject description:
PLATO, ESA's third M-class mission, aims to detect **Earth analogs**—small planets with long orbital periods—by monitoring stellar brightness variations with high precision. One of the key challenges in this mission is ensuring that detected transit signals are correctly interpreted and classified, especially those that are expected from an Earth-analog.
The aim of this PhD thesis is to develop an **optimized algorithm** for the detection and subsequent **scientific classification** of transits in stellar light curves, such as those expected from the upcoming M3/ESA PLATO mission. The goal is not only to detect potential transiting exoplanets but also to assess their scientific nature by distinguishing between genuine planetary signals and false positives.

Machine Learning techniques have demonstrated **high performance** in exoplanet transit detection from high-precision photometric light curves. Our model, **Panopticon**, has been specifically designed to meet the **instrumental needs of PLATO** and is fully operational (Vivien, Deleuil, et al., in press). This new approach offers two main advantages over traditional methods:

1. No prior data reduction is required, preventing transit signals from being lost when filtering out stellar activity.
2. Detection is possible after a single transit, eliminating the need for multiple observations or periodicity in the events, a key factor in the search for Earth analogs.

Initially developed for simulated PLATO data, Panopticon has also been successfully applied to TESS light curves, proving its robustness across different datasets.

PhD Objectives & Research Plan

This PhD aims to extend Panopticon's capabilities to prepare for the analysis of future PLATO observations, with a focus on classification. Since transit events can be of stellar origin (e.g., eclipsing binaries) rather than planetary, the model needs to incorporate false positive identification using the full set of PLATO observational data, including:

- Double aperture photometry
- Centre of brightness (CoB) curves
- Imagettes and individual camera light curves
- Physical parameters of the target star

The PhD research will be structured as follows:

Phase 1: Preparation of Realistic Training Data (Months 3)

- Generate labeled datasets for Machine Learning training and performance testing.
- Implement automated labeling of light curves using planetary orbital properties and injected eclipsing binary (EB) signals at the pixel level.
- Use the PLATOSim mission simulator, already operational on the LAM cluster, to create realistic datasets.

Phase 2: Model Adaptation for Multi-Source Data Ingestion (Months 6-14)

- Extend Panopticon beyond averaged light curves by integrating additional observational data:
    - Centre of Brightness (CoB) curves
    - Individual camera light curves
    - Various aperture photometry measurements
    - Physical characteristics of the target stars
- Modify the model architecture to optimally handle heterogeneous data sources and improve classification performance.

Phase 3: Development of Transit Classification Capabilities (Months 12-36)

- Implement classification features to identify:
    - Eclipsing binaries (EBs)
    - Background eclipsing binaries (BEBs)
- Train the model using the enriched dataset and optimize its performance for false positive rejection.
- Validate the model using both simulated data and real observational PLATO data when available.

By the end of the PhD, the Panopticon model will be upgraded into a fully integrated detection and classification tool, tailored to PLATO's specific observational strategy. This work will contribute directly to maximizing the scientific return of the mission by ensuring that only the most promising planetary candidates are selected for further analysis and follow-up observations. It will be a natural complement to the in-development planet detection automated software of the mission (Exoplanet Analysis System).

Additionally, the hands-on experience with CHEOPS transit data will provide the PhD student with expertise in working with real space-based photometric observations, strengthening their ability to handle the challenges of PLATO data analysis once available.

With the PLATO launch scheduled for late 2026, this PhD is particularly timely, as it will contribute directly to the mission's scientific preparation. Our team at LAM plays a key role in PLATO, being deeply involved in both scientific preparation and data processing. The proposed research will strengthen our contributions to the mission by refining exoplanet detection and classification strategies in anticipation of the first PLATO observations.

The PhD student will be involved in the international collaborations of the PLATO consortium. The Planetary Systems Group is actively involved in the development of new generation of ESA missions, CHEOPS and PLATO, but also on large radial velocity or imaging programs for the detection and characterization of exoplanets.

Bibliography:
[1] Vivien, H.., Deleuil, et al. 2024. *Panopticon: a novel deep learning model to detect single transit events with no prior data filtering in PLATO light curves. In press in A&A*
[2] Vivien, H., Caregas, I, Deleuil, M. Et al. , *Retrieving transits in TESS light curves using the panopticon deep learning model,* in preparation