LAM
LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE

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Title of the thesis subject: Architecture of PLATO planetary systems

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I) Description of the thesis subject

The three-dimensional arrangement of planets and their host star(s) in a planetary system is referred to as its architecture. It is a key tracer of the system's formation history, preserving the signatures of both the planets' original positions and their subsequent dynamical interactions following disk dissipation [1]. The PLATO space mission, to be launched in 2026, offers the opportunity to make a significant leap in our understanding of planetary architectures. PLATO will acquire extremely high precision photometry and detect the transit of planets, including Earth analogs. The ground follow-up of transits is an integral part of the mission, in particular radial velocity observations will provide mass measurements and have the potential to reveal non transiting planets.

The objective of this PhD is to develop tools to fully exploit the potential of PLATO to reveal planetary architectures. In particular it focuses on the following projects. It will involve applied mathematics, coding of a public software, as well as physical interpretation of the results.

Project A: Statistical Doppler imaging

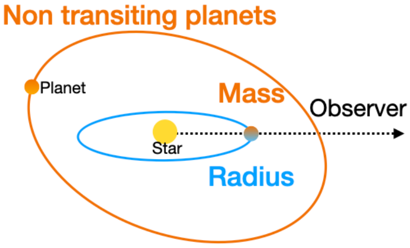
This first project aims to develop a new technique to retrieve stellar inclinations, a key aspect of planetary architectures [1], called statistical Doppler imaging. In classical Doppler imaging, one acquires a time series of spectra. The aim is to retrieve the pattern of magnetically active regions on a stellar surface, through the deformation they cause on the spectra as the star rotates. Individual regions might be too small to have a discernible impact. Statistical Doppler imaging is a novel technique that consists of combining the effect of the different active regions. It has been shown to enable the retrieval of the solar inclination with a few degrees accuracy, using SORCE photometry and HARPS-N radial velocities [2].

This technique is expected to have two by-products. First, it will improve the accuracy of mass and radius retrieval, as well as the ability to detect Earth-like planets. In the current state of development, the new models were already demonstrated to outperform existing Gaussian process model of stellar variability [2,3]. Second, they will provide a new way to study the patterns of magnetic structures on stars with a low level of activity, which presents an interest from the stellar physics point of view.

The new tools will be validated on archival data, and used in a systematic way on PLATO light curves and radial velocity follow-up.

Project B: PLATO populations

This second project aims to develop tools to analyse the PLATO observations at the population level, and compare the observational results with theoretical models of planetary formation.



Radial velocities and transit: what they measure.

Thanks to the radial velocity follow-up, PLATO has the potential to reveal non-transiting planets. Furthermore, asteroseismology will provide the age of stars. No other mission so far could provide such a statistically homogeneous and comprehensive view of planetary systems. The statistical tools to infer the true distribution of planetary systems from such observations do not exist yet.

This project aims to develop new statistical methods, able to correct for the complex observational biases of combined photometric and radial velocity measurements, and compare the results with the outcomes predicted by formation scenarios [4]. The methods will be applied to PLATO data.

III) Research plan

Project A: Statistical Doppler imaging (1 year)
- Developing the code that allows to transform physical simulations of magnetic activity into adjustable models.
- Validation on simulations
- Application to PLATO

Project B: PLATO populations (1.5 years)
- Development of the statistical framework, based on preparatory work by N. Hara (6 months + Application to archival radial velocity data (1 year)
- Application to PLATO (6 months)

Implication in SOPHIE consortium of the PhD student: The student will have the opportunity to observe on the SOPHIE spectrograph two weeks per year. As a regular observer, they will be associated to the publications of SOPHIE results.

The PhD student will have the opportunity to interact with an international network of collaborators.

References

[1] Winn & Fabrycky 2015, ARAA, vol. 53, p.409-447
[2] Hara & Delisle 2025, Astronomy & Astrophysics, Volume 696, id.A141, 32 pp
[3] Hara & Ford 2023, ARSIA, vol. 10, issue 1, pp. 623-649