Optimization of ground-based observing plans for PLATO

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Abstract

The PLATO mission will discover thousands of planetary systems by means of the transit method. These new systems will have to be confirmed with additional observations from ground observatories in order to discard false positive scenarios, and such additional observations will also be critical to further characterise the properties of the exoplanets such as their mass. To achieve this goal, several observational facilities providing for instance high-contrast imaging, and photometric and spectroscopic monitoring of the planet candidate host stars will have to be coordinated. The **Ground-based Observations Program (GOP)** is in charge of the infrastructure to coordinate all the observations, the gathering of the observational facilities that will participate in the project, the performance of the observations, and the quality control before sending the data to the PLATO Follow-up database (PFU-DB) for their analysis. Here, we present the design of these tools with particular focus on the **GOP Operational Centre** and the **scheduling system**.

GOP Operational Centre (GOPOC)

This system is the **core component managing the communication between subsystems and their tasks**. Its subsystems are:

- **Communications and Data Handling.** This is the hub responsible for retrieving the necessary data from the PFU-DB (planet candidates and properties), managing the data flow between the several GOP subsystems, storing the information and state of the performed ground-based observations, triggering the tasks for the progress of the candidates filtering or characterisation, and sending to the PFU-DB the data with the GOP outcome and its progress. The subsystem includes a data **Repository** to facilitate the operations, and an **Observer Interface** to interact with the observers transferring targets information and data.
- **Optimization & Scheduling.** This is responsible for the strategy and planning of observations (see right box).
- **Quality Control**. This subsystem assess, control, and assure the quality of observational data products delivered by PLATO GOP observers before sending them to the PFU-DB.

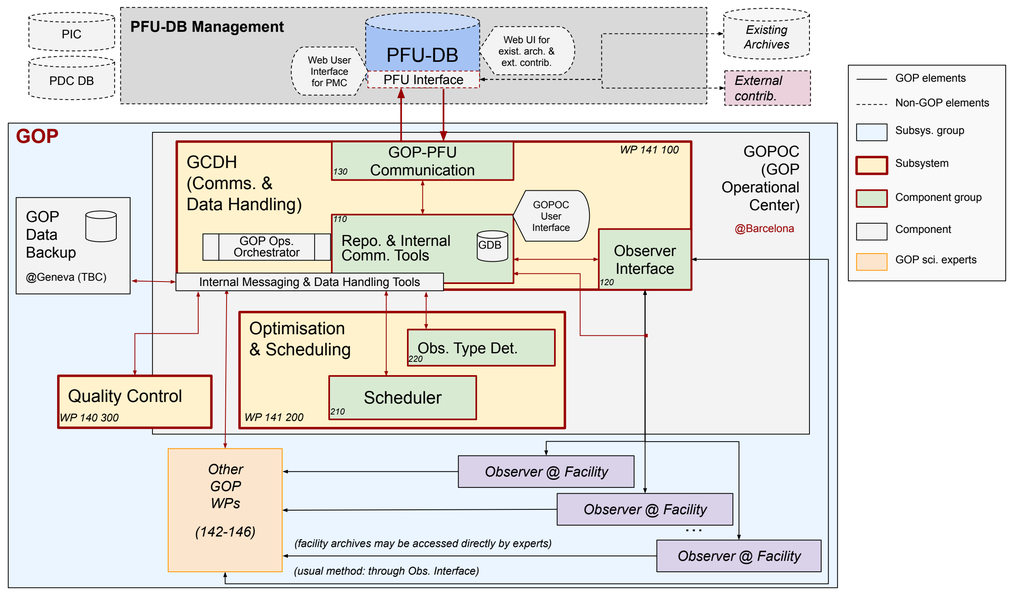

Figure 1: *General diagram of the GOP activities related to the GOP subsystems.*

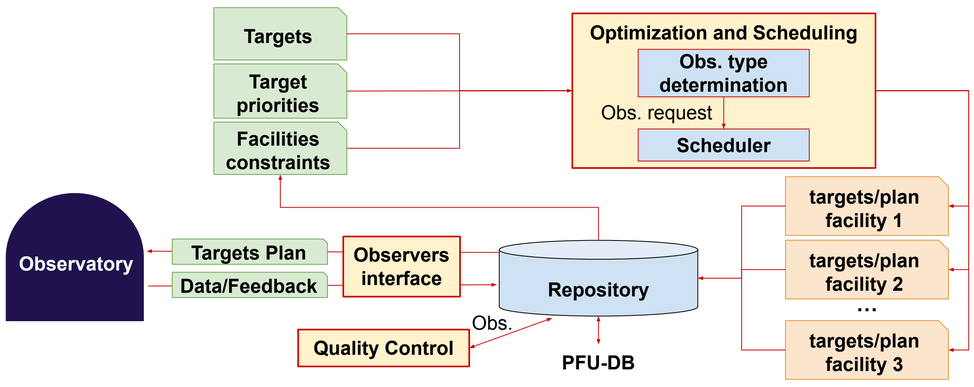

Figure 2: *Architecture of the GOP Optimization and Scheduling Subsystem.*

Optimization and Scheduling subsystem

The PLATO follow-up optimization and scheduling subsystem will be in charge of the **planning of the observations** necessary to confirm the PLATO exoplanet candidates and measure their masses (Figure 2).

Inputs

- Observational facilities and their availability
- Planet candidates and stellar host star properties
- Observing constraints and strategy

GOP Optimization and Scheduling subsystem components

- **Observation type determination.** This component determines the most appropriate type of observation to confirm planetary candidates (on-off photometry, low and high-resolution spectroscopy, high resolution imaging…), and when necessary the best observation strategy.
- **Scheduler.** This component produces optimized plans (Figure 3) taking into account the properties of the planets, the vetting strategy, and the defined observing strategy, as well as the capabilities of the facilities. It is based on the **STARS library** we are developing at IEEC for scheduling tools for different projects (Colomé et al. 2020, Garcia-Piquer et al. 2017, Morales et al. 2022, Nakhjiri et al. 2023). It is composed of two main subcomponents (Figure 4):
  - **Pre-scheduler:** computes the possible windows of observation for planet candidates taking into account visibility constraints.
  - **Optimization core:** distributes the targets between facilities and generates optimized plans using the pre-scheduler computed windows.

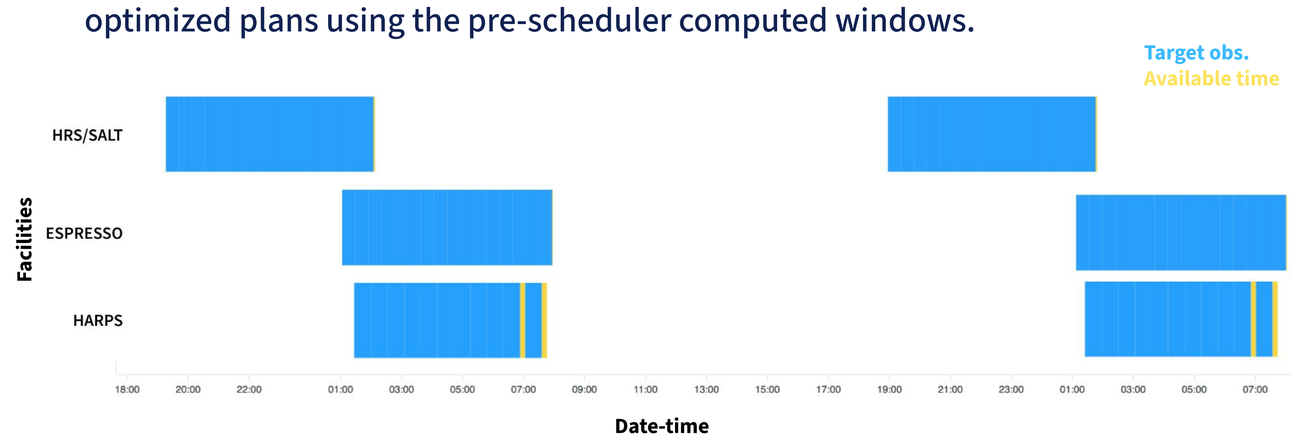

Figure 3: *Graphical representation of PLATO scheduler computed plans for three example facilities and two nights. Blue correspond to planned observations, and yellow to not scheduled available time.*

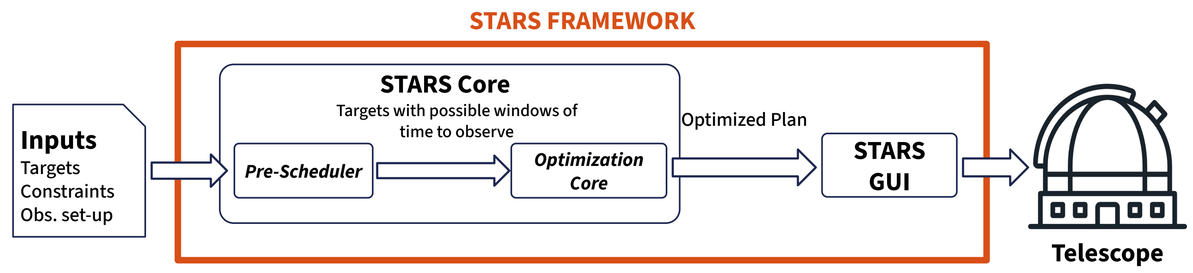

Figure 4: *Architecture of the STARS framework.*

STARS GUI

A Graphical User Interface is also under development within the STARS framework. It is a general tool to generate and visualize the optimized plans and evaluate their performance.

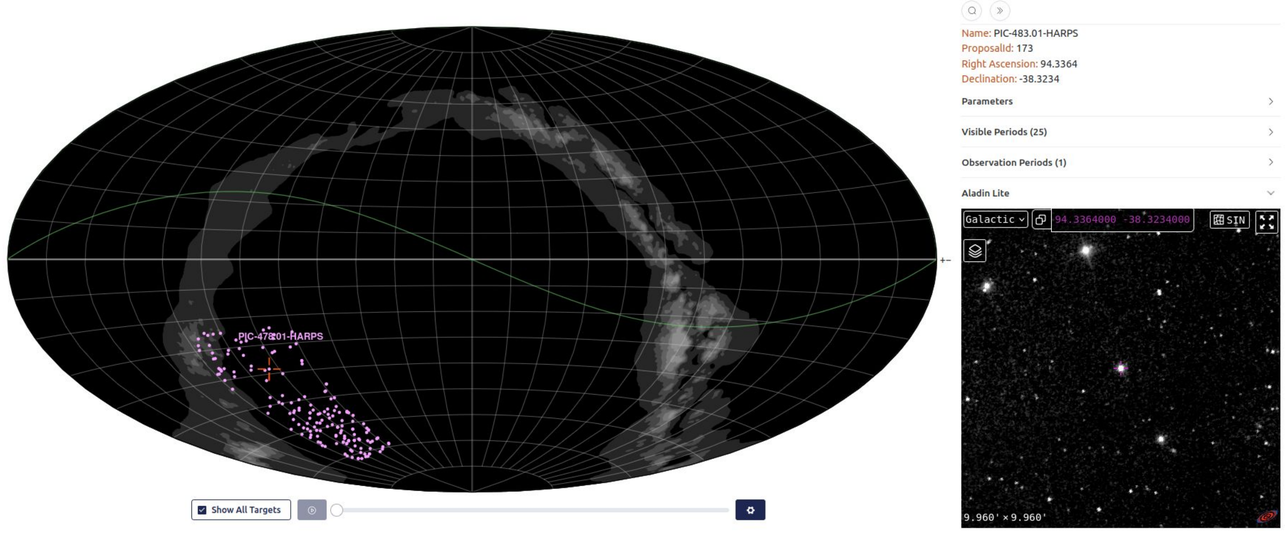

Figure 5: *Sky map representation of the targets included in an example optimized plan for one facility.*

GOPOC User Interface

A front-end graphical user interface for the GOPOC subsystem is under development in order to allow operators, schedule experts and GOP scientists to view the overall status of the subsystems, the observational plans, the progress of the observations and their quality flags.

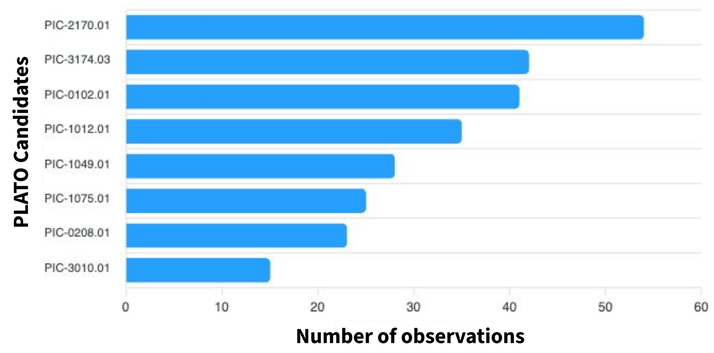

Figure 6: *Representation of the progress of the number of observations for each target.*

Bibliography

- Colomé, Nakhjiri, García-Piquer et al., 2020, ASP Conf. Series 527, 313
- García-Piquer, Morales, Ribas et al., 2017, A&A 604, A87
- Morales, Nakhjiri, Colomé et al., 2022, Exp. Astronomy 53, 807
- Nakhjiri, Salamó, Sànchez-Marré & Morales, 2023, Eng. Appl. of AI 126, 106856

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See also in this conference…

- *The PLATO Ground Observation Program*, by Stéphane Udry
- *Participation to the PLATO Ground-Based Observation Programme*, by Nami Mowlavi