CHEOPS GTO Highlights

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Chapter 1

Introduction

1.1 Context

This document describes the scientific Guaranteed Time Observation (GTO) program of the CHEOPS consortium. By its own nature CHEOPS is a *follow up mission*. The diversity of GTO programs is reflecting this optimisation. The aim of CHEOPS GTO is to provide us with a comprehensive scientific program focused on exoplanet science. Its goal is to get unique sets of data allowing us to make progress in our understanding how planets form and evolve with the goal to improve formation models for planetary systems and further explore diversity of structures. This program has been established by the Science Team of the CHEOPS consortium. It was initiated in 2016 by a call for ideas ("white call") followed by various ranking, critical reviews and updates concluding to the present format. The program is updated regularly, but at least once a year. New programs are added, some programs are stopped and removed from this document.

The science GTO program is technically structured in different topics with the goal to provide us with a comprehensive exoplanet science program. In this document, each science topic is called a *theme* and each of these *theme* is made of a series of specific *programs*. Every *program* is related to a unique science *theme* and is managed by a "Program Manager".

Implementation of targets in the RTL for each program is done with the help of the PHT-2 tool by each program manager. Implementation and update of target list is a dynamic process that may be done at any time with the exception of special periods when GO limitations are applicable. Some program are active but without target meaning it is fully defined and approved by the science team but the target list is not yet known or incomplete. Formally targets may not "belong" to a single program. In some cases they are shared between different programs and even different themes.

Progress of each program is regularly reviewed at least during each science team meetings. New themes are unlikely to be proposed but new program may be expected. In the course of the mission, when a program is completed (eg. not requiring further observations) it is removed from this document. The present document corresponds to a snap-short of program currently implemented and active in the GTO.

To ease organisation and tracking each theme is identified by specific name. A short description of each of them is listed below:

Transit Find: It aims at searching for transits of known planets discovered by other techniques, in particular radial velocity. Monitoring these systems with CHEOPS around the predicted transit times of their planets offers a straightforward way of obtaining both mass and radius for a sample of super-Earths and Neptunes orbiting bright stars.

MR improve: It aims at improving the determination of the mass-radius relationship for exoplanets in the low-mass range (below Saturn mass), and to relate it to planet formation and evolution models.

Atmo Characterize: It aims at measuring phase curve and secondary eclipses of transiting planets to gather information about their atmosphere.

Feature Characterize: It aims at the study "transit detailed features on known transiting planets with the goal of gathering information about their structure: love number or tidal factors, exo-moons and rings.

Explore: Explore program aims at discovering and characterising new planetary systems on bright nearby stars, focusing on multi-planet systems known to host transiting planets. This program will also search for dust clumps in edge-on debris disks.

Ancillary: This theme includes a set of programs related to planetary or stellar science relevant to the analysis and interpretation of data on exoplanets.

1.2 Overviews of research themes

Transit.Find

This science theme is at the heart of the original CHEOPS proposal: to study low-mass exoplanets orbiting nearby, bright stars, for which a wealth of information can be obtained with various instruments. The sample of RV-detected exoplanets is the starting point of this endeavour. Monitoring these known systems with CHEOPS around the predicted transit times of their planets offers a straightforward way of obtaining both mass and radius for a sample of nearby super-Earths and Neptunes. Originally it was seen as the only path forward to find the closest transiting planets to the Sun, including rocky bodies within the habitable zone of their host star. As of today the scientific context has evolved. Since the launch of the TESS new transiting system on brights stars are being detected. This change of landscape has been considered and in particular how to best build up on the expected dozens of transiting systems TESS will found around nearby bright stars. The Transit.Find theme continuously adjusts its strategy in order to identify the best opportunities in terms of scientific return in a very competitive landscape acknowledging synergie with TESS and unique CHEOPS capability.

MR.improve

The mass-radius relation is the first step towards the characterisation of the bulk properties. The knowledge of the planetary composition, in turn, is one key element to constrain planet formation, as it can be used to demonstrate, for example, transport of material in the proto-planetary disk. In this context, the structure of low mass planets is the most relevant. The theme is structured in four programs, three of them aim at measuring the precise radii of planets in different environments: respectively in systems with one transiting planet, in multi-planetary systems and around stars from various parts of the Galaxy. The fourth one is using transit timing variation as a tool to identify dynamical resonant states from multi-planetary systems where masses can be retrieved as the build-up of the system architecture.

Atmo.Characterize

Much of the observational effort in atmospheric characterization is focused on infrared observations. Key to this interpretation effort is the need to overcome degeneracies associated with the presence of aerosols and clouds in the atmosphere. A more realistic route towards breaking these degeneracies is to empirically determine the properties of the aerosols and clouds, including their reflectivity (on a global scale), sizes and compositions. This may be accomplished by measuring the geometric albedos and visible/optical phase curves of exoplanetary atmospheres. For highly irradiated targets, such as the extreme object KELT-9 b, these observations reveal the temperature distribution across the atmosphere, while highly eccentric systems, such as HD 80606 b, can be probed during periods of extreme heating at peri-center. CHEOPS also allows to target extremely hot short-period objects, such as 55 Cnc e, a super-Earth in one of the brightest known transiting systems. This object shows unknown source of variability in phase with the exoplanet itself. Exoplanets with extended envelopes believed to contain refractory species detected using Kepler and K2 will be added to the study if such objects are found.

Feature.Characterize

Planets close to their host star have an ellipsoidal shape due to the tidal effects potentially detectable in the transit light curve allowing us to measure the planet Love number providing insight into the planet internal structure. The main challenge of this program is to identify the change of shape signal from uncertainties in the limb darkening. Another potential visible dynamical effect is tidal dissipation resulting in a secular shrinking of the orbit. Detecting it would allow us to obtain a direct measure of the quality factor Q of a star. Fast-rotating stars exhibit significant oblateness, resulting in hotter, brighter poles and cooler, darker equatorial regions. This 'gravity darkening' effect can lead to asymmetric transit light curves, allowing the stellar inclination and obliquity angles to be measured. The obliquity (the angle between the stellar rotation and planetary orbital axes) can offer critical insights into the planet's migration history. Unexpected features (asymmetry, bumps, etc.) observed in transit light curve could also lead to detections of moons and rings.

Explore

This science theme aims at detecting and validating new planetary systems around bright stars (magnitude less than 11), focusing on multi-planet systems; enlarging the parameter space of both planets and host stars; measuring the orbital periods of transiting planets on wide orbits; exploring the architecture of systems hosting warm Jupiters via transit timing variation (TTV); discerning planet migration scenarios using TTV; studying in details dust clumps in edge-on debris disks around young stars; helping to unveil the nature of *enigmatic* objects.

Ancillary Science

Programs useful to the analysis of exoplanets data and to the interpretation of properties of exoplanetary systems have been grouped under the theme "Ancillary Science". These are stellar physics programs - like the study of stellar micro-variability; the derivation of precise limb darkening laws as function of stellar temperature; the measurements of stellar mass of M dwarfs in eclipsing binaries hosting a low mass star - and programs to address very specific questions in planetology, like the frequency of planets around evolved stars.