PLATO HIGH LEVEL SCIENCE REQUIREMENTS

Claude Catala for the PLATO Science Team

20 February 2008 V3.2

1. Basic science goals

The basic goal of PLATO is to detect and characterise a large number of planets and planetary systems. This will be obtained by observing the signatures of the planets transiting in front of their parent stars, and by using the same time series observations to perform seismic analysis of the planet-host stars. Combined with ground based follow-up observations, such as high resolution spectroscopy and interferometry, this will indeed enable a full characterisation of the planetary systems. The primary targets of PLATO are therefore stars that are sufficiently bright for such characterisation to be possible.

Exoplanetary transits with all characteristics (depth, period) in front of various types of stars will be investigated, leading to a full knowledge of exoplanet populations and allowing us to relate planet characteristics to central star properties for an unbiased statistical sample.

In particular, telluric exoplanets in the habitable zone will receive special attention. The mission design must be such that a statistically significant number of such planets can be studied.

Asteroseismic data from PLATO will be used to measure the star's mass and age, to confirm and improve the star's radius already known from Gaia, as well as to study the internal structure and internal angular momentum of planet host stars.

Groundbased high resolution spectroscopy will be used to confirm or measure the star's fundamental parameters (Teff, log g, chemical composition, rotation velocity, …), as well as to detect and measure radial velocity variations due to the orbiting planets and derive the planet/star mass ratio.

The knowledge of the planet/star radius ratio and planet/star mass function, coupled to the measurement of the star's radius and mass, will allow us to derive the planet characteristics (masses, radii, orbits, ages,…), assuming the stellar and planet ages to be equal.

Additional ground and space-based follow-up observations will also be obtained for the brightest targets, in particular in- and off-transit visible and IR photometry and spectroscopy, allowing us to derive information on the planet atmospheric composition and dynamics by differential observations.

In addition to these main goals involving the observation of a sample of bright stars, PLATO will also perform a more extensive survey of exoplanetary transits in front of a very large number of fainter stars. Also, in complement to the seismic analysis of planet host stars, asteroseismology of the many other stars present in the field of view will be used for a more complete study of stellar evolution. Observations of stars of all masses and ages, all across the HR diagram, including members of several open clusters and old population II stars, will be obtained for this purpose.

2. Basic observation strategy

The PLATO science objectives will be met using long uninterrupted high precision photometric monitoring of large samples of stars. These observations will first allow us to detect and characterise planetary transits, allowing us to measure planet sizes and orbital periods, as well as to detect planet satellites and rings.

They will provide us as well with measurements of frequencies, amplitudes and lifetimes of oscillation modes of the same sample of stars. The analysis of these asteroseismic measurements will yield precise information about the internal structure and rotation of these stars, and in particular will allow us to determine accurately their masses, radii and ages.

The mission will be divided in three phases. In the first two phases, long monitoring of two successive fields will be performed. A third step&stare phase at the end of the mission will be used to extend the sample of stars surveyed for short period planets and for stellar structure studies, as well as for revisiting targets of the first two pointings in an optimized way, to confirm longer period exoplanets.

3. PLATO high level science requirements

basic measurement principle – PLATO products

R0a : the PLATO satellite must provide long, very high duty cycle, high precision photometric time series in visible light of a large number of bright stars. The basic PLATO data products will be white-light curves with characteristics and of the stellar samples specified by the requirements below (see R2 and R5).
R0b : in addition, it is required that part of the payload (e.g. a small subset of the telescopes if a multi-telescope concept is chosen) provide photometric time series in at least two separate broad bands (see R8).
R0c : PLATO must also provide relative astrometric measurements of the targets of samples 1 and 3 (defined in R2 below).

surveyed field

R1a : two successive fields must be monitored, followed by a step&stare phase, during which up to 6 additional fields will be surveyed. During the step&stare phase, the instrument will also have to come back to the two fields observed during the two long monitoring phases.
R1b : at any one time, the surveyed field must be larger than 500 sq deg.
R1c : the location of the first field is around ecliptic coordinates (xxx,yy). The location of the second field is around (xxx,yy). During the step&stare phase, the instrument must be capable of accessing additional fields at any position in the sky, at a proper time for these observations to be feasible.

stellar samples

R2a : three complementary stellar samples need to be monitored :
sample 1 : > 100,000 stars to be monitored in the two successive initial pointings, with photometric noise level defined in R5a, typically with $m_V \leq 11\text{-}12$;
sample 2 : > 400,000 main sequence stars to be monitored in the two successive initial pointings, with photometric noise level defined in R5b, typically with $m_V \leq 14$;

sample 3 : >1000 stars monitored in the two successive initial pointings, with $4 \leq m_V \leq 8$;
R2b : these three samples will be completed by additional star samples to be observed during the step&stare phase.

duration of monitoring
R3a : the total duration of the monitoring of the first field must be longer than 3 years.
R3b : the total duration of the monitoring of the second field must be longer than 2 years (goal 3 years).
R3c : the step & stare phase at the end of the mission must have a duration of at least one year. During this phase, additional fields will be surveyed for at least 2 months and up to 5 months each. In addition, further visits of the previously surveyed fields will be organized in an optimized way to study long period exoplanets, and will possibly occur at any time during the step&stare phase.

time sampling and dynamical range
R4a : the sampling time for intensity measurements of stellar samples 1 and 3 must be shorter than 30 sec.
R4b : the initial sampling time for intensity measurements of stellar sample 2 must be shorter than 10 min.
R4c : the sampling time of targets in sample 2 after a first transit detection must be shorter than 30 sec, for a precise timing of further transits.
R4d : the sampling time for relative astrometric measurements of stellar samples 1 & 3 must be shorter than 10 min.
R4e : the required dynamical ranges of the samples above are as follows :
sample 1 : $8 \leq m_V \leq 11$,
sample 2 : $11 \leq m_V \leq 14$,
sample 3 : $4 \leq m_V \leq 8$.

photometric noise level
R5a : the photometric noise level must be below $2.7\ 10^{-5}$ in 1 hr for more than 100,000 stars monitored during the first two phases of the mission.
R5b : the photometric noise level must be below $8\ 10^{-5}$ in 1 hr for more than 400,000 stars brighter than m_V=14 monitored during the first two phases of the mission.
R5c : a photometric noise level of $2.7\ 10^{-5}$ in 1 hr must be achieved down to at least m_V=11
R5d : during the step&stare phase, the same levels of noise per hr must be achieved down to the same magnitudes as in the long initial phases.

Photon noise versus non-photonic noise
R6a : the photon flux of the target stars must be sufficiently high to ensure that photon noise complies with the photometric noise specifications R5a-c.
R6b : all other sources of noise must have a rms at least 3 times below that of the photon noise in the frequency range 0.02-10 mHz. Downward of 0.02 mHz, the non photonic noise level is allowed to rise gradually, to reach a maximum of 50 ppm per $\sqrt{\mu Hz}$ in Fourier amplitude space at a frequency of 3 μHz, for stars with m_V=11.

Overall duty cycle
R7a : gaps longer than 10 minutes must represent less than 7% (goal 5%) of the total observing time per target, for the longest observation period (3 years).
R7b : periodic gaps of any duration must represent less than 5% (goal 3%) of the total observing time, and less than 2% at any given frequency in Fourier space, over periods of 5 months.
R7c : the total amount of gaps, periodic or non periodic, of any duration, must represent less than 10% (goal 5%) of the total observing time over periods of 5 months.

Colour information
R8 : part of the payload must provide photometric time series in at least two separate broad bands. (see R0b). If a multi-telescope concept is chosen, at least two of the telescopes must provide photometric monitoring in at least two separate broad bands (one band per telescope). The photometric bands must be maximally separated, in such a way that the photon flux integrated in the common wavelength range represents less than 10% of the total photon flux. Less than 50% of the photons is allowed to be lost due to this broadband photometry.