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DOCUMENT

PLATO Science Requirements Document

PLATO SciRD v4 1.doc

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CHANGE RECORD

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Updated sensitivity numbers after input from Consortium	03-05-2011	12, 13, 15	R-SCI-110, R-SCI-160, R-SCI-220, R-SCI-342

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1 INTRODUCTION

1.1 Purpose

The purpose of this document is to specify the Science Requirements in relation with PLATO (PLAnetary Transits and Oscillations of stars) a proposed M-class mission of the Cosmic Vision 2015-2025 program. PLATO will build on the highly successful small CoRoT mission (CNES/ESA/Europe/ Brazil), and also on NASA's KEPLER mission, but will offer order of magnitude improvement of the science.

The PLATO proposal was selected for an assessment study as part of the ESA's Cosmic Vision 2015-2025 scientific plan, and requires ESA to build and construct a satellite that can for the first time observe planetary transits of a large enough sample to be:

- Statistically significant with respect to Earth-mass planets orbiting main sequence F-, G-and K-type (Solar Type) stars in the Habitable Zone
- Determine the radius and mass of both the parental star and the planet(s) orbiting it, with an accuracy of about 1%, as well as provide an age estimate of the detected exoplanetary systems to better than 10%
- Provide a planetary mass function extending from Brown Dwarfs down to planets smaller than the Earth.

The updated Science Requirements Document and the Mission Requirements Document will be the basis for the development work following the assessment study carried out by ESA, thus constituting the next phase of the study.

The scientific case described in this document has its origin in the ESA Cosmic Vision Proposal "PLATO PLAnetary Transits and Oscillations of stars", by C. Catala and the PLATO consortium, and the document PLATO Science Specifications V3.1 by C. Catala and the PSST team, and "Revised science goals for PLATO" by Don Pollaco for the PSST. It has been updated taking the results of the assessment study – as described in the Yellow Book reporting those results – into account.

1.2 Scope

The Science Requirements defined in this document address all the Science Requirements of the PLATO mission, as they are seen to impact on the mission requirements.

This document aims at showing clearly the links between the Science Requirements and individual performance requirements in order to help understand, trace and support the analysis of the relation between the mission, telescope and detector specifications on the scientific objectives of the mission.

In particular, four performance topics are deemed important as they relate to the Telescope and detector specification:

- Sensitivity and photometric accuracy
- Spatial resolution
- Field of view
- Wavelength range coverage

1.2.1 Revision

Exoplanet science and stellar evolution science are progressing rapidly, in particular due to recent advances in ground (Harps, Sophie, Super-WASP etc) and space (CoRoT, Kepler) based observations in these fields. In addition, recent and more thorough and reliable star counts exercises have shown that the number of bright cool dwarfs observable by PLATO had been previously over estimated. Based on these events, it was necessary to update the highest priority goals of PLATO. This first revision was carried out until January 2009.

A second revision has now been carried out, taking into account the results of the assessment study, and taking the document to February, 2010.

1.3 Document overview

We first describe the basic science goals and how they divide into the topics of a basic observation strategy and the selection of a baseline observation technique. The division into the two main topics – asteroseismology and exo-planetology follows naturally. In the next section we give the science goals, derived from first principles, and the rest of the document describes how these principles are converted into High Level Science Requirements. All science requirements have been updated to reflect the situation as seen by the PSST in February 2010.

2 SCIENCE GOALS

2.1 Basic Science Goals

The prime objective of the PLATO mission is to search for planetary transits (occultations) in front of stars that can be fully characterized in terms of fundamental physical parameters. This characterisation is done both using the PLATO data themselves via asteroseismology, and from the ground using e.g. high resolution spectroscopy. Specifically, this applies to the following scientific goals:

1) *The Detection of Earth Analog systems*. By this we mean the ability to find transits of terrestrial planets around solar type stars, in particular in their habitable zone. The primary sample of these host stars can be fully characterised in terms of ages and size (the heart of the PLATO mission).

2) *The search for exoplanets* ***around the brightest stars of solar type*** *at all orbital periods and with all physical sizes*. These objects (which could also include Earth Analogue systems) will be most sought after as they will be ideal targets for follow up observations, e.g. transit spectroscopy, with the leading facilities of the time (e.g. the ELT, JWST and later space missions).

3) *The search for exoplanets* ***around dK and dM stars up to few hundreds of parsecs*** *at various orbital periods and with all physical sizes in a significant fraction of the sky (several tens of thousands stars including the Step & Stare phase described below)*. These objects will also be privileged targets for further characterization work.

4) *Very bright stars, of all types that can be fully characterised using seismic analysis*. Even amongst this sample there is a significant probability of exoplanet transit detection.

In essence these aims are actually much the same as those contained in the original proposal but we have now ***prioritised the brighter and most nearby samples*** (even at the expense of the faint limit).

The asteroseismic data from PLATO will be needed in order to measure the stellar masses and ages. The stellar radius will already be known to a high degree of accuracy from data obtained with the Gaia spacecraft, but together with the asteroseismological data it allows as well to study the internal structure and internal angular momentum of planet host stars to an unprecedented level.

As has been shown by NASA's Kepler space craft (in January, 2010), the planetary parameters can be determined with a precision that is at least one order-of-magnitude higher than with any other method. Ground based high resolution spectroscopy will be used to confirm or measure the star's fundamental parameters independently, as well as to detect and measure radial velocity variations due to the orbiting planet and to derive the planet/star mass ratio.

The knowledge of the planet/star radius and mass ratios, coupled to the measurement of the star's radius and mass, will allow us to calculate each discovered planet's characteristics. The planetary age will be estimated assuming that it is the same as that of the star. We expect also here to reach unprecedented accuracies.

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 the seismic analysis of planet host stars, which represents the highest priority goal of the mission, asteroseismology of the many other stars present in the field of view will be used to study 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.

2.1.1 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 characterize 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 will allow us to determine accurately their masses, radii and ages.

The science observations will be divided in two phases:

- The Long-Duration Observation Phase: two successive fields will be monitored.
- The Step&stare Observation Phase: extends 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.

Both long and short-term pointings will be considered in order to complete the sky coverage.

2.1.2 Basic observation techniques

In the proposal leading up to the selection of PLATO for study, two options for the actual implementation were visualised. These two are referred to as respectively, 'spinning' and 'staring' concepts. The former was envisaged as having three separate telescopes with optical axes separated by 120° and rotating to sweep out a great circle on the sky, followed by periods of detailed observation of certain fields. The latter, was conceived as having more but smaller telescopes and pointing for a long period of time (years) towards the same position. Both were seen in the proposal as fulfilling the scientific requirements as what concerned the objectives of:

- achieve the required photometric position
- have long enough uninterrupted time series to reach the scientific goals
- observe enough stars in order to have a statistically significant sample of exo-planetary targets within the required magnitude range

Both concepts were evaluated during a first internal study at the Concurrent Design Facility (CDF) at ESTEC. The conclusion was that the 'spinning' concept did NOT fulfil the scientific objectives as what concerned the number of reachable targets. The recommendation of the PLATO Science Study Team was that since the spinning concept did NOT reach the goals as what concerned the number of targets one should proceed with the 'staring' concept.

2.1.3 Exoplanets & space missions

At the time of writing, more than 400 exoplanets have already been detected from the ground in various (indirect) ways. The methods used include transits (as proposed for PLATO), radial velocity measurements of the parental stars line-of-sight movements (the first successful method) and gravitational lensing. Recently a number (~ 20) of exoplanets have been detected, using transits, from the CNES/ESA/European/Brazilian spacecraft CoRoT (Convection, Rotation and planetary Transits). The latter, which has been in orbit for more than three years, has similar objectives to PLATO, i.e. exoplanets and asteroseismology, but with three crucial differences. First, the star sample explored for planet transit detection is much fainter than expected for PLATO, leading to severe difficulties for ground-based confirmation and planet mass measurements. Second, asteroseismology and exoplanetology are carried out on ***different*** targets. This means that the precision with which the fundamental stellar and planetary parameters can be determined is much less than what is the objective of PLATO. The third difference is that CoRoT can only observe a target field for a maximum of about 150 days, which implies that a detection (which ideally requires at least three observations) of a planetary transit can be recorded for orbital periods of < 50 days. Except for the intrinsically weakest of stars, we are then talking about planets which are too hot to be able to sustain life as we know it, and also objects which have no analogue in our own Solar System (the innermost planet Mercury with an orbital period of 88 days is already very hot).

PLATO is designed to detect and characterise planets of the same type as the Terrestrial planets in the Solar System (Venus, Earth, Mars), orbiting within the inner part of their systems, where they could in principle be the hosts for life. No such objects have been detected with ground based methods, and no exo-planetary system have to date been recorded that appear to be similar to our own (i.e. with a Jupiter-like planet in the same place as our own Jupiter). It is clear that a mission like PLATO is required for the detection of such.

2.1.4 Asteroseismology

One major aspect of the asteroseismology programme of PLATO will be to provide direct and model-independent measurements of the masses and radii of the central stars of the detected exoplanets. Estimates of the ages of these stars with a precision better than 10% will also be obtained from the seismic analysis.

Additionally, the asteroseismology programme of PLATO will bring considerable advances in our understanding of stellar internal structure and evolution. In spite of recent progress, our description of some physical processes controlling stellar structure and evolution is subject to major uncertainties. Convection and various other mixing and transport processes are poorly understood and yet play a major role in stellar evolution, determining evolution timescales, and must be taken into account when measuring stellar ages. Our current poor knowledge of most of these processes results in determinations of stellar ages that are strongly model-dependent and unreliable. Considering these difficulties, it is clear that the age ladder of the Universe, which rests on stellar age estimates, is also still highly unreliable.

Our modelling of stellar interiors and stellar evolution therefore needs to be seriously improved. The situation for the Sun has evolved considerably with the advent of helioseismology, which has provided precise insight into the properties of the solar interior. Asteroseismic investigations, i.e. measurements of oscillation frequencies, amplitudes and lifetimes of a large number of stars of various masses and ages constitute the only and necessary tool to constrain efficiently our modelling of stellar interiors, and improve our understanding of stellar evolution.

The pioneering CoRoT space mission is now bringing us essential information in this area, by providing high precision asteroseismic measurements for a few dozen stars distributed in several regions of the HR diagram. The Kepler mission will also include a limited asteroseismology programme. However, these first measurements will remain limited to small and strongly constrained samples, which do not contain for example members of open clusters, or old population II stars, which would constitute major targets for such investigations. A better and more complete exploration of seismic properties of various classes of stars, sampling all stellar parameters (mass, age, rotation, chemical composition) is necessary. Such is the goal of PLATO.

3 SCIENCE REQUIREMENTS

The PLATO High-level Science Requirements are all derived from a few simple principles that clearly identify PLATO as an order-of-magnitude evolution of the CoRoT and Kepler spacecraft. These principles are:

To observe a large enough sample of solar type stars to be able to draw conclusions about the presence of Earth size planets in Habitable Zone orbits. A large enough fraction of this sample shall be bright enough to allow for stellar parameters to be determined from asteroseismology. From the science goals outlined above, we have derived a set of scientific specifications.

First, it is clear that the highest priority objective of PLATO is to detect and characterize terrestrial planets in the habitable zone of cool dwarfs, via their transits. The characterization of the detected planets requires a precise and reliable characterization of their host stars, including via seismic analysis, which will be used primarily to determine their mass, age and performing an independent estimate of the radius of the stars. The core star sample for the PLATO mission will consist of stars that are bright enough to reach the photometric precision required for seismic analysis, namely 27 ppm in 1 hr. Each star with a detected transit will have to be followed up from the ground, including with high precision radial velocity measurement, in order to confirm that the detected event is indeed due to a planet, and also in order to measure the mass of the planet.

Given the low probability to detect planet transits, we estimate that at least 20,000 such stars need to be surveyed for a sufficient amount of time to detect habitable orbits, i.e. typically for 2 to 3 years. This would represent a very significant improvement compared to Kepler, considering in addition that such exoplanetary systems detected by PLATO would also be fully characterized. Additionally we would expect to detect many transits of larger planets around these stars.

Below, these principles are converted into a set of High-level Science Requirements.

3.1 Data Products

R-SCI-010	PLATO shall provide photometric time series of a large number of bright stars. The basic PLATO data products will be white-light curves with characteristics of five stellar samples (see Section 3.3).
R-SCI-020	PLATO shall provide relative astrometric measurements of the targets of stellar samples 1, 2 and 3.
G-SCI-030	(Goal) Part of the payload shall provide a photometric time series in at least two separate colour broad bands (see Section 3.4).

3.2 Fields

Nominal science operations consist of two phases:

- Long-Duration Observation Phase
- Step&Stare Observation Phase

R-SCI-040	During the Long-Duration Observation Phase, two fields shall be observed for at least 2 years (goal 3 years).
R-SCI-050	The centre of fields observed during the Long-Duration Observation Phase shall be located above 60 degrees or below -60 degrees in ecliptic latitude.
R-SCI-060	During the Step&Stare Observation Phase, several fields shall be observed for between 2 and 5 months, when feasible due to the position of the Sun. *The number of fields during the Step&Stare Observation Phase depends on the duration of each observation. Either a small number of fields can be observed for a long time (5 months), or a larger number for a shorter time (2 months), or any combination of the above. This will be a matter of optimization of the mission return, and can be decided only when the first results are known.*
R-SCI-070	The centre of fields observed during the Step&Stare Observation Phase shall be located at any ecliptic latitude.

3.3 Stellar Samples

The number of cool dwarfs and subgiants down to m_V=11 must be maximized, as these are the stars for which ground-based radial velocity follow-up will be most effective.

The first sample is the backbone of the PLATO mission, and must be considered as the highest priority objective.

For the second and third samples it has also been recognized that observing very bright stars will provide significant facts about the physics of a large number of different stellar classes. Further, the detection of a number of short period planets around such bright stars will also be used as input for future instruments (e.g. JWST) aimed at characterizing exo-planetary atmospheres.

The fourth sample, composed of nearby M dwarfs, will result in a survey of planets orbiting nearby very cool M dwarfs. These stars are cool enough that their habitable zone is relatively close-in, therefore planets in the HZ have orbital periods of just a few days. This, combined with the fact that the stellar radius is only a fraction of that of the Sun, will facilitate the detection of small transiting planets. Given the favourable contrast between the planet and the star in these cases, spectroscopic characterization of the planet atmospheres in infrared transit spectroscopy, although challenging, will be achievable by further follow-up observations.

Finally, the fifth sample is derived from the requirement to observe an even higher number of stars with a sufficient precision to detect telluric planets around solar-type stars, which is 80 ppm in 1 hr, but without seismic analysis. For these detections, we will rely on other, less precise and less reliable techniques to assess the mass and age of the host stars. These other methods, e.g. based on a correlation of stellar rotation with age, will likely be improved by a proper calibration using with the seismological measurements of the P1 sample. The minimum number of such stars is 250,000. As for the first sample hundreds of transiting larger planets can be expected. This sample is clearly of lower priority than the others and the minimum number of 250,000 stars is therefore a goal rather than a requirement..

These five main samples may be complemented by additional star samples to be observed during the Step&Stare phase.

3.3.1 Stellar Sample 1

R-SCI-080 The total number of targets in stellar sample 1 (cumulative over all fields) shall be at least 20 000 dwarf and subgiant stars later than spectral type F5.

R-SCI-090 The dynamic range of stellar sample 1 shall be $m_V \leq 11$.

R-SCI-100 Stellar sample 1 shall be observed during the Long-Duration Observation Phase, for a duration defined in R-SCI-040.

R-SCI-110 The photonic noise level for stellar sample 1 shall be below 34 ppm in 1 h.

R-SCI-120 The sampling time of stellar sample 1 shall be shorter than:

- 50 sec for intensity measurements
- 600 seconds for relative astrometric measurements.

3.3.2 Stellar Sample 2

R-SCI-130 The total number of targets in stellar sample 2 (cumulative over all fields) shall be at least 1000 dwarf and subgiant stars later than spectral type F5.

R-SCI-140 The dynamic range of stellar sample 2 shall be $m_V \leq 8$.

The dynamic range quoted here gives an approximate range. The photonic noise level is prioritised.

R-SCI-150 Stellar sample 2 shall be observed during the Long-Duration Observation Phase, for a duration defined in R-SCI-040.

R-SCI-160 The photonic noise level for stellar sample 2 shall be below 34 ppm in 1 h.

R-SCI-170 The sampling time of stellar sample 2 shall be shorter than:
- 50 sec for intensity measurements
- 600 seconds for relative astrometric measurements.
- 50 sec for relative astrometric measurements for which potential transit events have been identified (TBC).

G-SCI-180 (Goal) 300 stars, located anywhere on the HR diagram, shall be observed with colour information (i.e. can include types earlier than F5).

3.3.3 Stellar Sample 3

Stellar sample 3 is an extension of stellar sample 2 into the Step&Stare Phase. Since it may only be possible to observe a limited number of bright stars in stellar sample 2, sample 3 observes additional bright stars during the Step&Stare Phase.

R-SCI-190 The total number of targets in stellar sample 3 (cumulative over all fields) shall be at least 3000 dwarf and subgiant stars later than spectral type F5. The 1000 stars in sample 2 are included in sample 3.

R-SCI-200 The dynamic range of stellar sample 3 shall be $m_V \leq 8$.

R-SCI-210 Stars in stellar sample 3 that are not included in sample 2 shall be observed during the Step&Stare Observation Phase, for a duration defined in R-SCI-060.

R-SCI-220 The photonic noise level for stellar sample 3 shall be below 34 ppm in 1 h.

R-SCI-230 The sampling time of stellar sample 2 shall be shorter than:
- 50 sec for intensity measurements
- 600 seconds for relative astrometric measurements.
- 50 sec for relative astrometric measurements for which potential transit events have been identified (TBC).

3.3.4 Stellar Sample 4

Stellar sample 4 is specifically directed to a survey of cool M dwarfs in the solar vicinity, both using the long pointing phases and the Step&Stare phase of the mission.

R-SCI-232	The total number of targets in stellar sample 4 (cumulative over all fields) shall be at least 10,000 cool M dwarfs, with at least 5,000 monitored during the long pointing phases of the mission, and more than 5,000 during the Step&Stare phase.
R-SCI-234	The dynamic range of stellar sample 4 shall be $m_V \leq 16$ for the long pointing phases, and $m_V \leq 15$ for the Step&Stare phase.
R-SCI-236	The photonic noise level for stellar sample 4 shall be below 800 ppm in 1 h.
R-SCI-238	The sampling time of stellar sample 4 shall be shorter than: • 600 sec for initial intensity measurements • 50 seconds for targets for which potential transit events have been identified. • 50 sec for relative astrometric measurements for which potential transit events have been identified (TBC).

3.3.5 Stellar Sample 5

G-SCI-240	(Goal) The total number of targets in stellar sample 5 (cumulative over all fields) shall be at least 245 000 dwarf and subgiant stars later than spectral type F5.
R-SCI-250	The dynamic range of stellar sample 5 shall be $m_V \leq 13$.
R-SCI-260	Stellar sample 5 shall be observed during the Long-Duration Observation Phase, for a duration defined in R-SCI-040.
R-SCI-270	The photonic noise level for stellar sample 5 shall be below 80 ppm in 1 h.
R-SCI-280	The sampling time of stellar sample 5 shall be shorter than: • 600 sec for initial intensity measurements • 50 seconds for targets for which potential transit events have been identified. • 50 sec for relative astrometric measurements for which potential transit events have been identified (TBC).

3.4 Wavelength and Colour Information

R-SCI-290	The payload shall provide high precision photometric time series in the wavelength band of 500 nm (goal 450 nm) to 1000 nm.
G-SCI-300	(Goal) Part of the payload must provide photometry in at least two separate colour broad-bands.

G-SCI-310 (Goal) The photometric bands shall be separated so that the photon flux integrated in the common wavelength range represents less than 10% of the total photon flux.

G-SCI-320 (Goal) In the colour-discriminating portion of the payload, less than 50% of the photons are allowed to be lost due to this broad-band spectrophotometry.

3.5 Saturation and Noise

R-SCI-330 Stars brighter than the max dynamic range shall not impede operation of the instruments, except by modifying the number of useful pixels.

R-SCI-340 During the Step&Stare Observation Phase, target stars shall be observed with the same levels of noise per hour and magnitudes as in the Long-Duration Observation Phase.

New stars and stars from the Long-Duration Observation Phase that are revisited must be observed with the same performance.

R-SCI-342 The maximum non-photonic noise at frequencies between 20 μHz – 10 mHz shall remain below 0.54 ppm/√μHz (expressed in Fourier amplitude space) for stars of magnitude $m_V = 11$.

This is derived from the science requirement that the non-photonic noise shall be less than one third of the photonic noise for stellar sample 1, which is 34 ppm in one hour (1.6 ppm/√μHz in Fourier amplitude space).

R-SCI-345 The maximum non-photonic noise at frequencies below 20 μHz shall increase monotonically up to a maximum of 50 ppm/√μHz (expressed in Fourier amplitude space) at 3 μHz for stars of magnitude $m_V = 11$.

The power spectral density (PSD) limit of non-photonic noise is shown graphically in Figure 3-1.

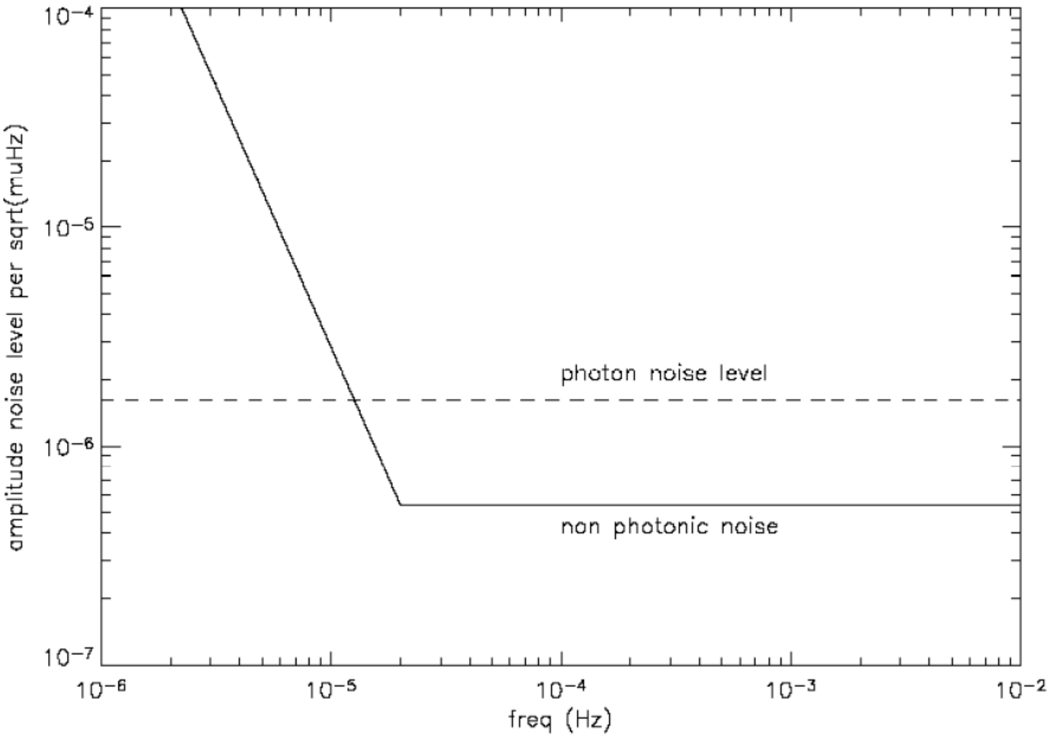

Figure 3-1: Non-photonic noise requirements in Fourier amplitude space for stars with m_V=11

3.6 PSF and Stability

The Point Spread Function (PSF) is allowed to expand within specified limits due to spacecraft jitter and other high-frequency effects, but its excursion on the detector between exposures must be kept below a specified (see below) value. The cut-off frequency of 1 Hz was selected since it is sufficiently higher than the cadence of fast detectors (~0.4 Hz).

R-SCI-350	The jitter at frequencies above 1 Hz much be such that the resulting spread of the PSF shall be less than 1.5 arcseconds
R-SCI-355	The PSF shall be positionally stable on the detector with a stability performance increasing monotonically from 1.5 arcseconds to 0.2 arcseconds on timescales between 1 second and 2.5 seconds (i.e. all frequencies between 1 Hz and 0.4 Hz).
R-SCI-360	The PSF shall be positionally stable on the detector to less than 0.2 arc seconds on all time scales between 2.5 seconds and ~14 hrs (i.e. all frequencies between 0.4 Hz and 20 ⌠Hz).

R-SCI-365 The PSF shall be positionally stable on the detector with a stability performance decreasing monotonically from 0.2 arcseconds to 19 arcseconds on timescales between ~14 hours and 92 hours (i.e. all frequencies between 20⌈Hz and 3 ⌈Hz).

G-SCI-370 (Goal) The shape of the (defocused) PSF shall approach a top-hat function with an area of ~3-4 CCD pixels.

From model calculations it is derived that minimising source confusion and signal saturation requires that the ideal shape should be a top-hat function.

G-SCI-380 (Goal) 90% of the energy from a target star shall fall within an area of 2×2 pixels on a detector.

3.7 Observation Gaps

“Gaps” are defined as time during which science observations are suspended while other spacecraft operations are performed.

R-SCI-390 During nominal science operations, any gaps with duration shorter than 10 minutes shall constitute less than 3.5% (goal 2.5%) of the time per month.

R-SCI-400 During nominal science operations, any gaps with duration longer than 10 minutes shall not last more than 25 hours (goal 14 hours) each with a maximum frequency of one per month.

The two requirements above minimise the loss of potential planetary transits. The maximum allowable loss is 7% (goal 5%) of observation time during one month, divided in long and short gaps.

R-SCI-410 In addition to R-SCI-390 and R-SCI-400, periodic gaps concentrated in the 0.02-10 mHz band must be less than 5% (goal 3%) of elapsed time over periods of 5 months, and no more than 2% at any given frequency.

There cannot be unacceptable levels of gaps in the frequency bands of scientific interest specified here; otherwise, the science value of the output data is degraded.

R-SCI-420 Total periodic and aperiodic gaps shall constitute less than 10% (goal 5%) of elapsed time over periods of 5 months.

3.8 Performance Assumptions

The following assumptions should allow a useful figure of merit to be provided which facilitates the optimisation of designs to satisfy the above summary requirements derived from more detailed science requirements.

3.8.1 Assumption 1: Cool Dwarf and subgiant Density

The following table lists star densities for cool dwarfs (F5V-K3V range) per square degree. Values for magnitudes 1-4 and 1-5 are not statistically significant.

Mag range m_V	Star density (stars per deg^2)
1-6	0.0236
1-7	0.0781
1-8	0.311
1-9	1.116
1-10	4.9
1-11	14.1
1-12	47.1
1-13	160.1

Table 3-1: Cool Dwarf Density for Various Magnitudes

3.8.2 Assumption 2: Photon Count Rates

The brightness in front of the telescope of a typical solar type star (G0V, T_{eff}=5940 K) is determined to be $4.6\ 10^6 * 10^{-0.4m}$ photons / (s cm^2), where m is the visual magnitude.

Figure 3-2 describes in a functional form the cumulative density of stars as a function of magnitude. It is based on stellar counts on photographic plates in one possible region of interest. The three lines represent the following:

- The blue line is an approximation of the stellar count: $(m_V) = (3.61*10^{-11})\ (m_V^{11.85})$
- The black line represents the actual star density obtained from USNO-B1.0
- The red line represents the objects in the fields for which the B-R colour cannot be used to make an accurate estimate of the V magnitude, and the R-I colour had to be used or a G2V spectrum was assumed

It should only be used to derive a relative figure of merit comparing different potential designs. (If the preferred field changes, the provided relation will be updated). The star density model provided here can be used to estimate confusion etc.

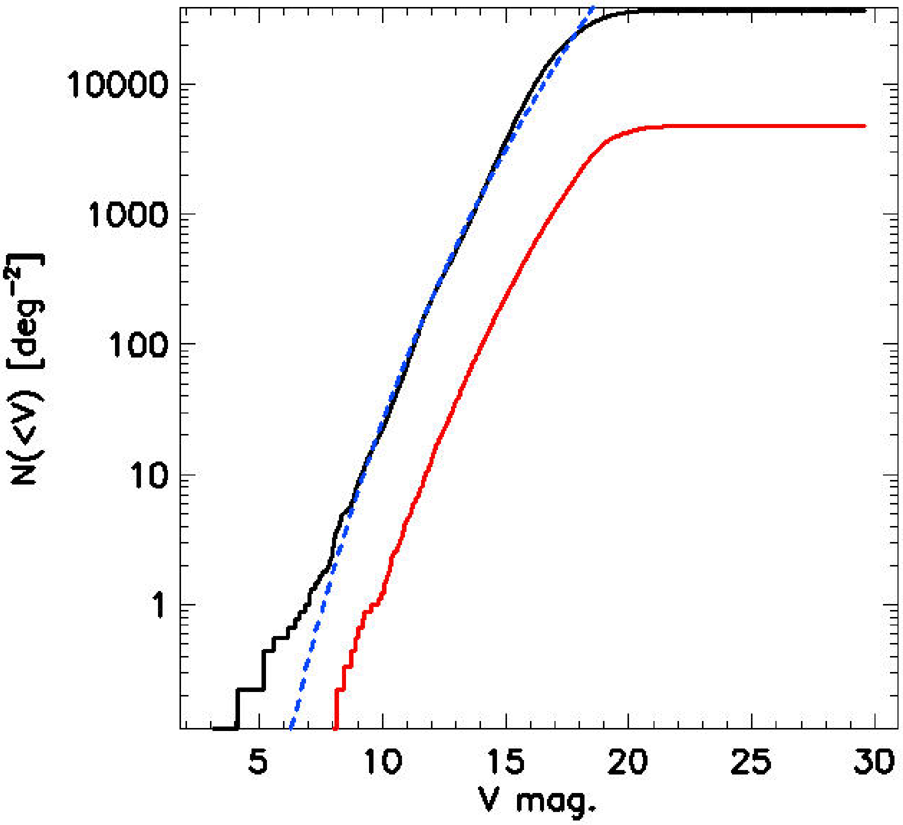

Figure 3-2: The number of stars per square degree brighter than magnitude m_V

4 ACRONYMS

CDF	Concurrent Design Facility
CNES	Centre National d'Etudes Spatiales
CoRoT	Convection, Rotation and planetary Transits
ELT	Extremely Large telescope
ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
JWST	James Webb Space Telescope
PLATO	PLAnetary Transits and Oscillations of stars
PSST	PLATO Study Science Team