PLATO – Science Goals

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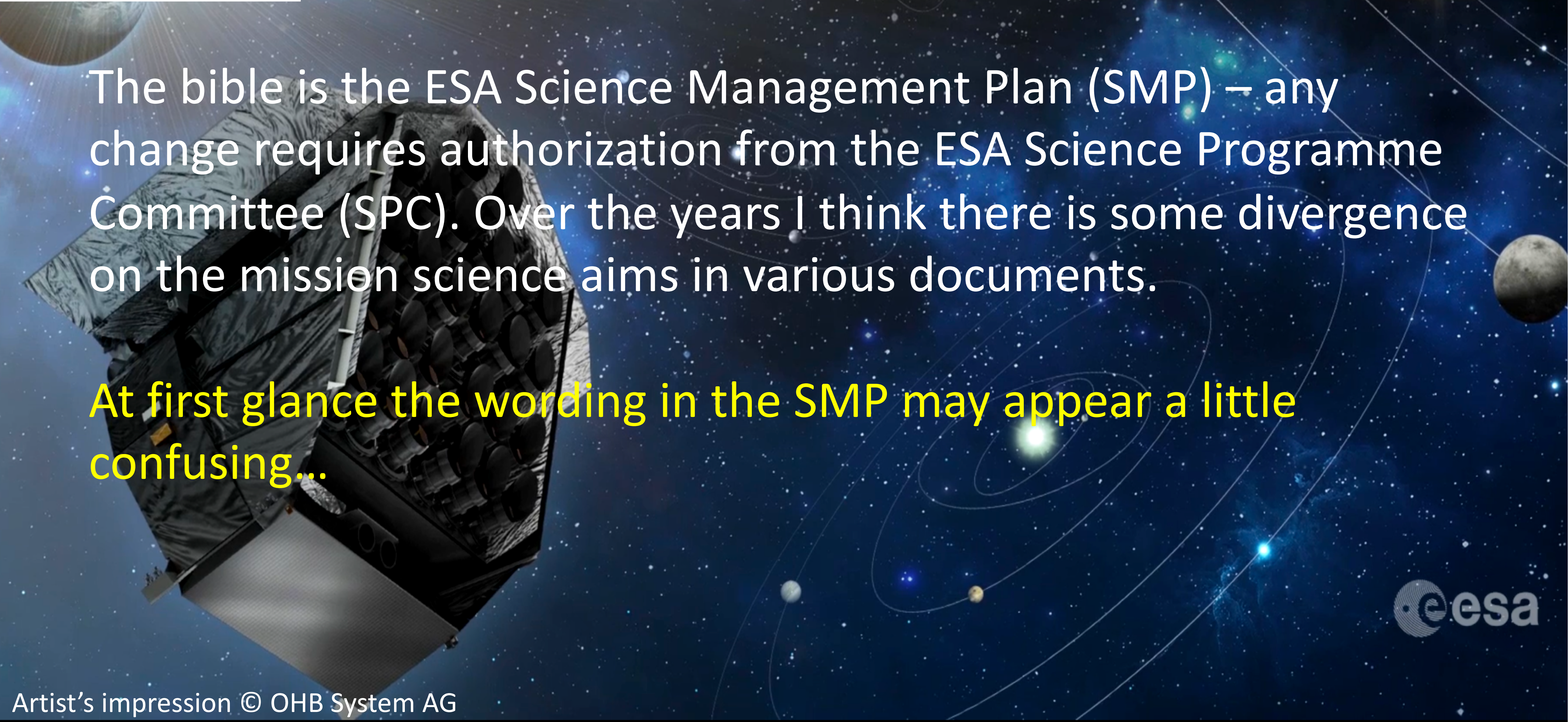
The bible is the ESA Science Management Plan (SMP) – any change requires authorization from the ESA Science Programme Committee (SPC). Over the years I think there is some divergence on the mission science aims in various documents.

At first glance the wording in the SMP may appear a little confusing…



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Scientific Questions

From the SMP there are three Science Questions that PLATO will investigate

01 – How do planets and planetary systems form and evolve?

02 – Is our Solar System special or are there other systems like ours?

03 – Are there potentially habitable planets?

The Questions are evidenced by seven Science Objectives

Scientific Objective 1/7

S1 - Determine the bulk properties (mass, radius and mean density) of planets in a wide range of systems, including terrestrial planets in the habitable zone of solar-like stars.

PLATO will determine planet bulk properties to explore the diversity of planets which in turn allows us to constrain planet formation models. Furthermore, terrestrial planets in the habitable zone will be identified that will be prime candidates for being potentially habitable planets.

Supports O1, O2, O3.
Measurements: Photometry of ~15K (20K) solar like stars with m<11 at 34ppm in1hr. RV > 100 (400) planets.
Results:: >100 (400) exoplanets with orbits, radii (3%), masses (10%) over all sizes and mean densities including 5 (30) (super-)Earths in the HZ

Scientific Objective 2/7

S2 - Study how planets and planet systems evolve with age

The age of planetary systems provides new constraints on planet formation models and allows the planetary (system) properties to be correlated with temporal evolution processes when the ages of planet hosts are accurately determined. Furthermore, the seismic characterisation of a large sample of bright stars across the HR diagram will lead to improved stellar models, allowing for substantially more reliable age characterisation of stars in general.

Supports O1, O2, O3.

Measurements: Asteroseismology for >5K stars with $m<11$ and 34ppm in 1hr

Results: >100 (400) planetary hosts with ages (~10%) and planets with accurate densities.

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Scientific Objective 3/7

S3 - Study the typical architectures of planetary systems

The architecture of planetary systems includes parameters such as the distribution of planet masses and types (terrestrial or gaseous) over orbital separation, the co-planarity of systems, and orbital parameters in general. These provide constraints on planetary system formation and evolution processes.

Supports O1, O2.

Measurements: Photometry of >245K stars with m<13. RV for >100 (400) planets and mass determination from TTVs and upper limits.

Results: Planet distribution of orbital parameters for >4K (7K) planets at lower accuracy; for >100 (400) planets with accurate masses (~10%); for a sub-set of planets, with TTV determined masses.

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Scientific Objective 4/7

S4 - Analyse the correlation of planet properties and their frequencies with stellar parameters (e.g., stellar metallicity, stellar type)

The correlation of planet parameters with stellar properties provides constraints on planet formation and allows the planetary diversity to be characterised. Stellar properties are furthermore key parameters in the study of the potential habitability of planets.

Supports O1, O2, O3.
Measurements: Photometry of >15K (20K), M-dwarfs and stars across the HR diagram, RV for 100 (400) planets; mass determination from TTVs and upper mass limits.
Results: Well-known stellar parameters (age accuracy ~10%) for >5K stars => improved stellar models. Characterised hosts of hundreds of planetary systems.

Scientific Objective 5/7

S5 - Analyse the dependence of the frequency of terrestrial planets on the environment in which they formed

Planets form in different regions of our Galaxy, in clusters and around field stars. Correlations of planet occurrence frequency with their environment will provide constraints on planetary formation processes.

Supports O1.
Measurements: Photometry of >245K stars with m<13.
Results: >4K (7K) detected planetary transits from different regions in the sky

Scientific Objective 6/7

S6 - Study the internal structure of stars and how it evolves with age

Determining planet host star parameters requires improving today's stellar models and stellar evolution in general by measuring asteroseismic pulsations of stars. Well-known stellar models from asteroseismology and cross-calibration with classical methods will be key in obtaining planet host star parameters to address the overall science goals.

Supports O1, O2, O3.
Measurements: Asteroseismology for >5K solar-like stars with m<11 at 34ppm in 1hr.
Results: >5K bright stars for which asteroseismic modes determined with high precision to improve stellar models (age accuracy ~10%)

Scientific Objective 7/7

S7 - Identify good targets for spectroscopic follow-up measurements to investigate planetary atmospheres

Planets identified around the brightest stars will represent the “Rosetta stone”-like objects for spectroscopic follow-up. This will allow their atmospheric structure and composition to be investigated. These planets will provide a wealth of information by which to study planetary formation and evolution and, for terrestrial planets, study potential habitability.

Supports O1, O3.
Measurements: Photometry of ~1K stars with m<8 with 34ppm in 1hr. Photometry of 5K M-dwarfs with m<16
Results: >10 (30) planets around bright stars and >100 transits around M-dwarfs from different regions of the sky.

PLATO methods

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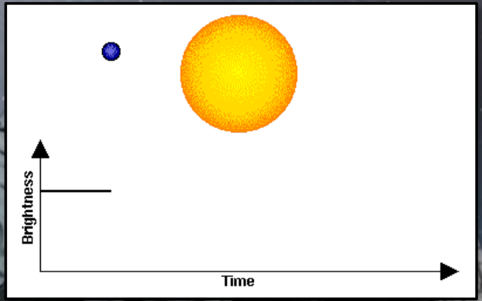
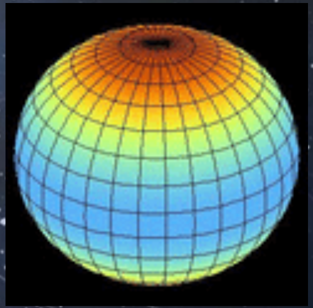
Satellite photometry



Transit detection

→ radius ratio
→InclinationPlanet /star

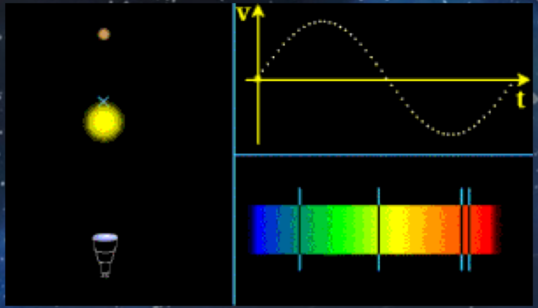


Asteroseismology

→ Stellar radius, mass
→ Stellar age

→**Planet radius**
→**Planet age**

Ground-based spectroscopy



RV spectroscopy

→ **Planet mass**

characterized

PLATO precisions: The benchmark case: An Earth around a Sun at V= 10 mag:

→ **3% radius;** → **10% mass;** → **10% age**

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Complimentary Science

In addition, PLATO will address a large number of complementary and legacy science topics. Asteroseismology analyses of massive stars and compact stars at the end of their lives will be undertaken. Due to its capability to observe in many directions of the sky, PLATO will sample a much wider variety of time-variable phenomena in various populations of the Galaxy than hitherto. PLATO's asteroseismic characterisation of stellar ensembles, binaries, clusters and populations will be a significant addition to the Gaia data. For example, PLATO will be able to determine accurate ages of red giant stars up to 10 kpc in our Galaxy which, together with the information on distances and chemical composition obtained by the Gaia mission, will significantly enhance our knowledge of the structure and evolution of the Milky Way.

Implications for PLATO observations:

Objectives (1-7) to the definition of a number of samples
S1 >15K (20K) solar-like stars with m<11
S2 1K stars with m<8

S4 5K M-dwarfs with m<16
S5 >245K stars with m<13

In addition SMP discusses a ‘Prime Sample’ as targets (number?) from the PIC that are to be observed with high PLATO accuracy defined before launch. Ground based support for planet candidates in this sample.

Thoughts…

With GAIA input, the PIC will be well characterised and well tailored to the requirements of the samples.

However, Its unlikely that S1-4 will have much “contamination”.
Implications – Giants from S5, binaries in S5 (?), what else?

Objects in S5 will mostly have photometry obtained on board.

=> We will need a workshop on the composition of S5.

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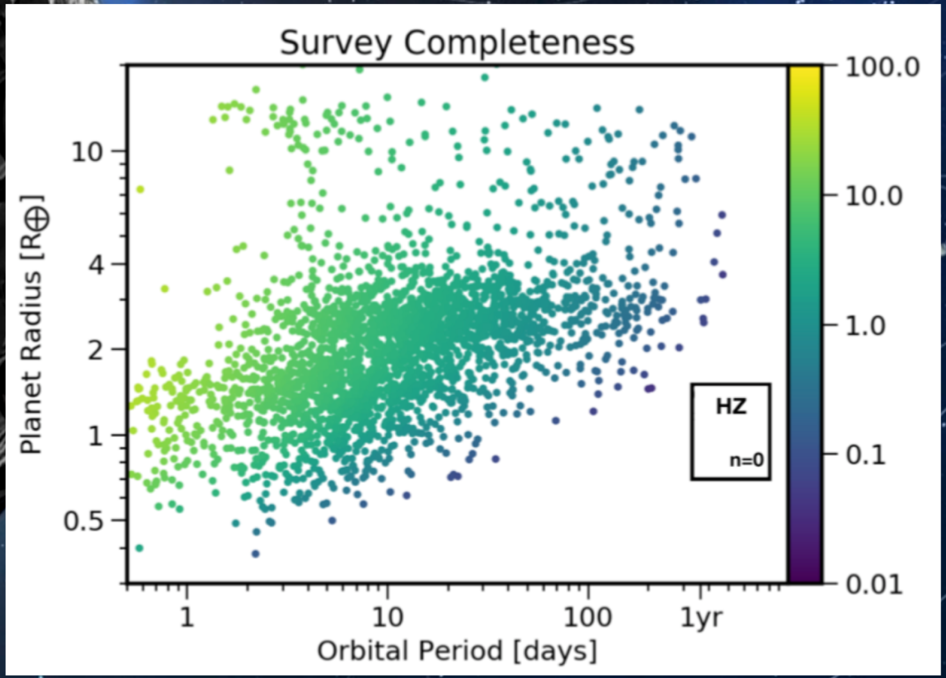
The need to remain flexible:

Historically my view of S5 was this was incremental on Kepler and given that the photometry was on board I was less interested. However, application of GAIA results to Kepler planet hosts:



$\eta_\oplus$ currently undefined for solar like stars: Further implications for S5

Summary

Science Reminder: PLATO will detect transit signals of thousands of planets which are bright enough for radial velocity spectroscopy to determine their masses.

While PLATO will provide :

- A sample of well characterized “Earth-Sun” analogues ⇨ Unique to PLATO
- Small planet diversity ⇨ How unique is the Earth
- Planets at all ages, understand planet evolution ⇨ Unique to PLATO
- Provide a target list for atmosphere spectroscopy ⇨ JWST, ARIEL, ELT etc

Don’t forget the important developments in stellar evolution.

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