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Asteroseismology in PLATO. A necessary tool for characterizing planetary systems

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Abstract

Today, the field of stellar physics is witnessing a significant boost thanks to the progress of asteroseismology from space with satellites like CoRoT and Kepler, which will be exploited to its full power with the PLATO mission now under development. Both the study of stellar interiors and the analysis of exo-planetary systems have mutual benefits since not only they share similar techniques for obtaining the data (analysis of light curves) but also the high precision with which today asteroseismology can provide the global parameters of stars is crucial to accurately and precisely characterize the planetary systems. In this contribution I briefly describe this symbiosis.

1 Introduction

The European Space Agency (ESA) selected the PLATO 2.0 space mission (PLAnetary Transits and Oscillation of stars) in February 2014, as the M3 mission to be launched in 2024. The main objective of PLATO 2.0 is to detect, and mainly, characterize the bulk properties of terrestrial exoplanets in the habitable zone of bright solar-type stars. The exoplanets will be detected by the weak eclipses they produce when transiting in front of their parent star, while the long uninterrupted observations will allow also to analyze the oscillations of these stars, yielding their internal structure and evolutionary state. Since main targets will be bright ($V < 11.5$), PLATO 2.0 will be able to confirm planets candidates using radial velocity (RV) measurements from ground-based spectroscopy, providing thus a complete characterization of the exo-planetary systems. Spain will contribute to the PLATO 2.0 instrument by providing the Focal Plane Assemblies of its 34 telescopes, as well as the Main Electronics Units which

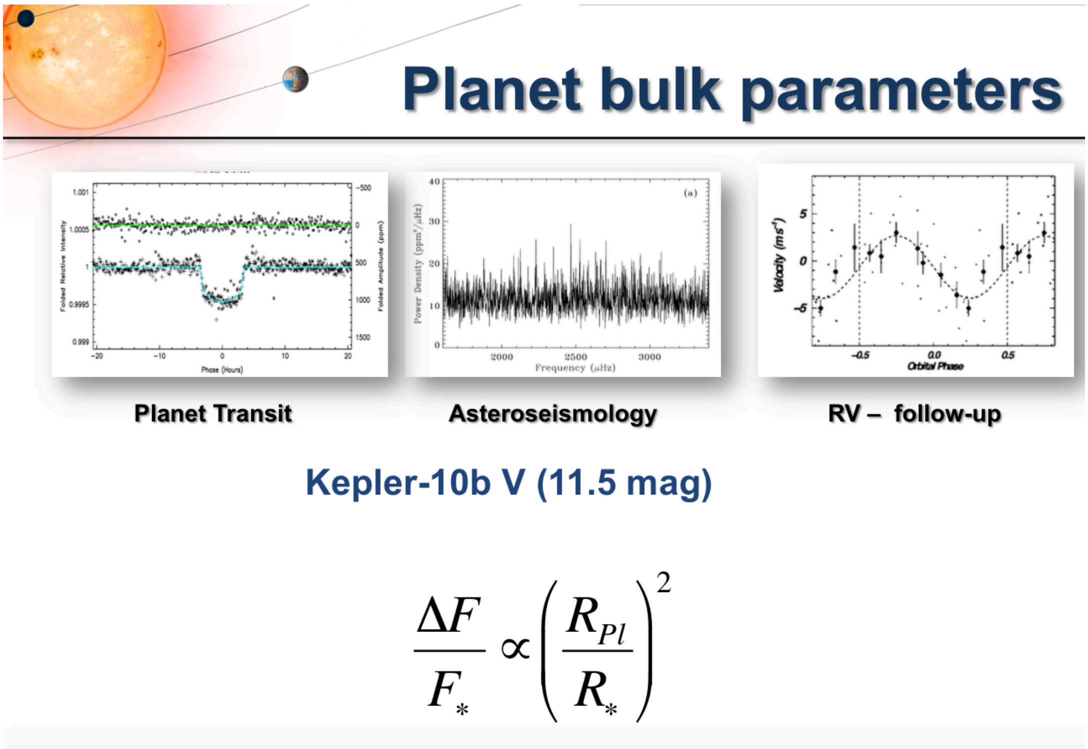

Figure 1: Example of a planet (Kepler-10b) detected by the Kepler satellite, showing stellar oscillations and whose transit was confirmed and characterize by radial velocity measurements. The host star has V=11.5 magnitudes. The precision of the planet radius depends directly on the precision of the stellar radius. This is one of the key points of asteroseismology which, for certain stars, can provide accurate measurements of the radii and ages.

will perform onboard and in real time the photometric extraction of the stellar light curves. More details about the mission and the Spanish contribution can be found in the proceedings [4], [6], and [9] of this conference.

2 The symbiosis

Asteroseismology is the astrophysical branch that studies the structure of stars by probing the stellar interiors by the analysis of the waves that propagate in their interior. Nowadays, it is the only available technique able to determine the characteristics of the stellar internal structure and the physical processes therein (see, e.g., [1] for a monograph on the subject). This makes possible to accurately obtain the stellar bulk parameters which determines the related parameter precision for its orbiting planets (see Fig. 1). Indeed, asteroseismology is the only technique that allows accurately dating planetary systems by dating the host star. Furthermore, since asteroseismology is currently boosting our knowledge of stellar

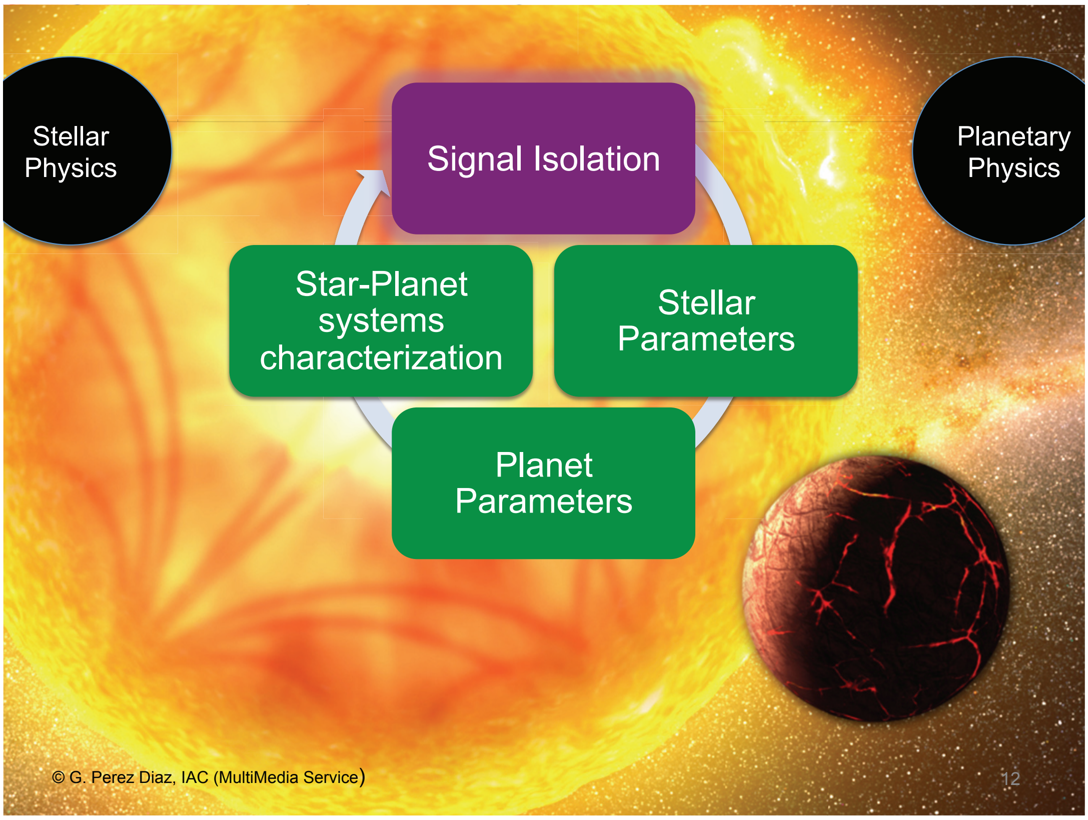

Figure 2: General scheme of synergies and symbiosis between asteroseismology and exoplanetary sciences. From the observational point of view, the signal isolation is crucial for distinguishing between planets and oscillations (and noise sources). From the scientific point of view, the precise bulk parameters of host stars are crucial to derive accurate and precise planets parameters. Image credits by G. Pérez Díaz (IAC multimedia service).

structure and evolution, it is expected that the preparation of the PLATO2.0 mission will take advantage of the current analyses and projects for a better exploitation of previous missions (e.g. CoRoT [2] and Kepler [3] legacy data). In particular PLATO 2.0 will measure the oscillation frequencies more than 80,000 dwarf and subgiant stars with $V < 11$. In total, one million stellar photometric light curves will be obtained over the course of the full mission, for which asteroseismology will provide accurate and precise measurements for the proper characterization of the planetary systems and individual stars. This simbiosis (see Fig. 2) thus explains and justifies why asteroseismology belongs to the core of PLATO 2.0 mission.

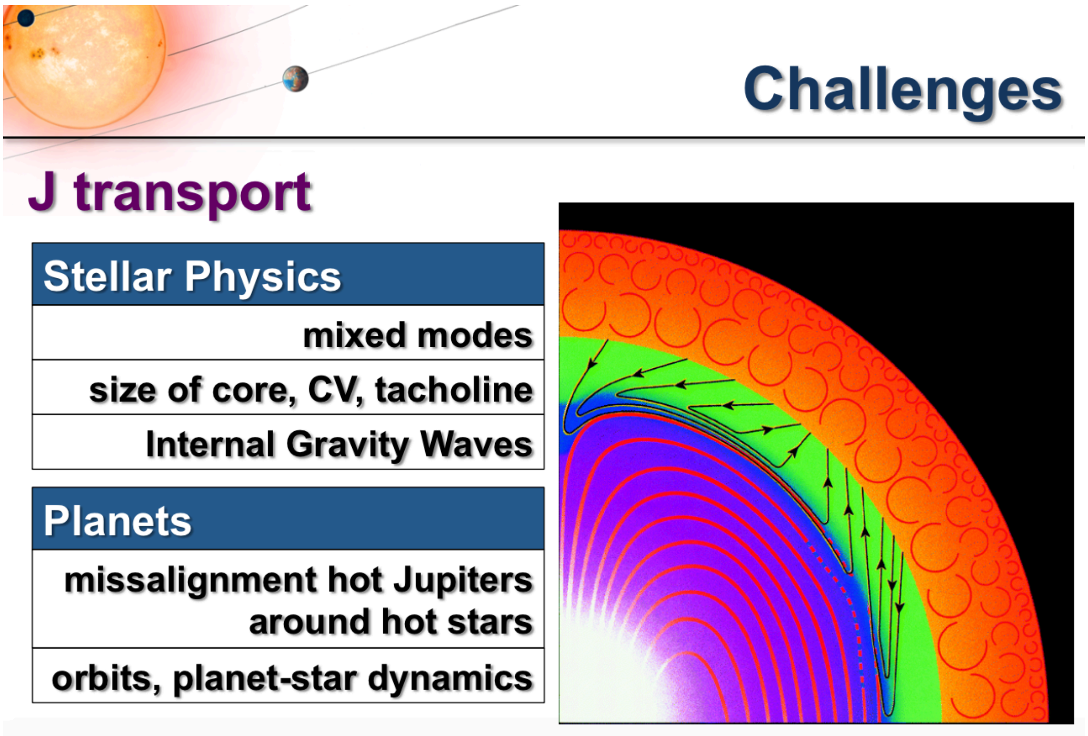

Figure 3: Some of the current big challenges in stellar structure and evolution which will be partially or fully tackled by PLATO2.0 thanks to asteroseismology using high-precision space data.

3 The challenges

The main challenges to which asteroseismology plays a crucial role is the main objective of the mission, since PLATO 2.0 is expected to provide stellar masses with an accuracy of better than 10%, stellar radii to 1-2%, and ages to 10%. In addition, Gaia [10] will provide the distances to the stars via direct, geometrical measurements, and hence the true absolute luminosity of the star can be derived with high accuracy. Combining the luminosity with the effective surface temperature of the star obtained from (ground-based) high-resolution spectroscopy, PLATO 2.0 will obtain the radius of the star with 1-2% accuracy. Also, luminosities from Gaia can be used in cases where Teff has not been measured. Notice that Gaia will be complete down to $V \sim 20$ magnitude, while Plato will observe stars between $V = 4 - 16$ magnitude, so all PLATO 2.0 targets will also be observed by Gaia.

Furthermore, the recent boost of asteroseismology has put on the table some important answers regarding the internal structure and evolution of stars (see the mission reference paper [11] for exhaustive detail of the different scientific objectives and complementary science covered by the mission), but also has raised important questions to be solved. Discussion of all of them goes beyond the scope of this contribution. Here we intend to provide a glance of the big challenges that PLATO2.0 will be able to face to (see Fig. 3). Among them we find the angular momentum distribution and transport in stellar interiors. Thanks to asteroseismology it is possible to have, for certain stars (like the Sun and some red giant stars) an estimate of the internal rotation profile both radially and as a function of the latitude in the stellar surface.

Recent research indicate that important angular momentum coupling between the core and the envelope of evolved stars is missing in current models (e.g.[7], [8], and [5]). Internal gravity waves (IGW) has been proposed (e.g. [12]) to leave observable surface light fluctuations at a level of hundreds of micromagnitudes. They showed that IGWs are very efficient in transporting angular momentum in stars and, in particular, can be responsible for spinning up or/and slowing down their outer layers which may be at the origin of the misalignment of hot Jupiters around hot stars, the Be class of stars, nitrogen enrichment anomalies in massive stars, and the non-synchronous orbits of interacting binaries. PLATO 2.0 can explore the theory of excited IGWs, a major missing ingredient in stellar evolution theory, by deriving internal rotational profiles from inversion of rotationally split oscillation frequencies for a carefully selected sample of target stars covering entire evolutionary paths.

4 Conclusions

The asteroseismology is nowadays a powerful astrophysical branch that boost our knowledge of the internal stellar structure. This allows, for the first time, to test different stellar evolution theories and hypothesis about the physics of stars never reached so far. The importance and relevance of asteroseismology is well recognized in the PLATO 2.0 mission since it will be the first space mission to systematic characterize the observed planetary systems using this technique. But even beyond that, asteroseismology offers promising possibilities for tackling scientific frontier problems, like the angular momentum distribution and transport in stellar interiors, its connection with stellar pulsations and other physical phenomena in the interior of stars, like convection. This latter is another major poorly known processes in stellar interiors, and PLATO will be able to study with data of unprecedented precision.

For the exploitation of the asteroseismic data, Spain counts with several teams distributed around the country's geography, like a team at IAC (Instituto de Astrofísica de Canarias) specialized in Helioseismology and asteroseismology of solar-like stars, a team at UGR (University of Granada) and IAA-CSIC (Instituto de Astrofísica de Andalucía - CSIC) specialized in classic pulsators, sdBs, theoretical studies of pulsations in M stars, as well as in the study of time series analysis techniques, a team at UV (University of Valencia) expert in Be stars, a team at UVigo (University of Vigo) specialized in sdB stars, and other key people working at CAB-INTA-CSIC, IEE-CSIC and other universities, that participate in some of the scientific work packages of the mission consortium, which are directly or indirectly related to asteroseismic inferences from the PLATO2.0 data.

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