3. Characterization of exoplanets and their stars in anticipation of PLATO

A. Context and state of the art

The discovery of exoplanets has opened new possibilities to study planets around other stars, learn about their compositions and understand their formation. The CNES-led CoRoT, launched in 2006, led the way in terms of space missions dedicated to the discovery and characterization of exoplanets, soon followed by the NASA mission Kepler. Many ground-based surveys (HARPS, WASP, HATnet, to name but a few) were also conducted with great success. This has brought a number of striking announcements, from the determination of the frequency of occurrence of planets (around ~10% per star for giant planets, but an order of magnitude more for smaller planets), the realization that planets could be very tightly packed and orbit very close to their parent star, the detection of atomic and molecular species in exoplanetary atmospheres, etc.

We should expect the pace of discoveries to continue: the ability to detect and characterize exoplanets has opened a new window to the Universe and we have only seen so far our closest, brightest neighbors, planets very close to their stars or the largest ones and/or the observations have been limited to a small region of the sky. This is about to change, in particular with the missions TESS and CHEOPS (to be launched in 2017), but more importantly thanks to PLATO (to be launched in 2024) which will look for exoplanets in transit over a large fraction of the sky with unsurpassed accuracy and sensitivity.

Because of the extremely significant number of targets to be detected and characterized by PLATO, new tools are to be developed. First, the exoplanet host stars have to be characterized as best as possible in part because the uncertainty on their physical parameters directly affect the ability to characterize their exoplanets and because stars and planets are intimately linked. This requires a number of supporting observations, from high-resolution spectroscopy, high-resolution imaging, radial velocimetry, interferometry, etc. Second, statistical tools must be used to either seek or confirm correlations between quantities. Third, theoretical models must be developed to interpret the observations. Finally, we must prepare future observations and in particular the spectroscopic characterization of exoplanetary atmospheres.

B. Current activity

We have experience both in modeling the structure and evolution of exoplanets, in astrometry through our direct participation in GAIA and generally in high resolution observations by interferometry. We are directly involved in the preparation of PLATO through the leadership on WorkPackages "Composition and formation of ice and gas giants" (PI: T. Guillot) and "Analysis of GAIA spectroscopic performance" (PI: A. Recio-Blanco).

Thanks to our direct participation to CoRoT, we have extensive experience in modeling the structure, evolution and composition of exoplanets [e.g., 1,2]. We have also worked on modeling the atmospheres of irradiated atmospheres, producing the first analytical non-grey solution of radiative transfer for these planets [3]. Coupling atmospheric and evolution models enables us to efficiently calculate evolution models to determine their global composition. This work has been done individually for CoRoT planets [1], but we are now extending the approach to the ensemble of known exoplanets as part of a collaboration with M. Havel and V. Parmentier. We expect to confirm the correlation between stellar and planet metallicity that we had discovered [4], this time with a much higher significance.
Separately, the discovery of a statistically significant number of exoplanets allows new possibilities. We are currently working with D. Lin (UCSC) on tidal interactions between stars and planets to

understand how close-in massive planets may be swallowed by their parent star. In order to be able to analyze the data and make predictions, we must understand better how angular momentum is removed from these systems through the magnetic braking of stars. This is part of the PhD thesis of L. Sadeghi Ardestani.

Finally, we are also working with M. Kunitomo (Nagoya Univ.) and S. Ida (ELSI, Japan) to understand how the presence of planets may affect the composition of the parent star. The strength of this correlation depends on the formation mechanism (see Theme 6.1) and on the pre-main sequence evolution of stars that we can simulate using the MESA stellar evolution code.

The combination of this work is essential prepare the scientific background for PLATO and identify the key questions to be addressed by the mission, beyond the detection of the small, habitable planets and the characterization of the planets themselves.

C. Future steps

The next step is to really consider the information that is to be collected through a statistical approach. For this, we need to treat

D. International collaborations

We are collaborating with Mathieu Havel (Columbia University, USA), Vivien Parmentier (University of Arizona, USA) and M. Kunitomo (Nagoya University, Japan)

E. List of people involved in the project

Tristan Guillot (30% ETP) with PhD student Leila Sadeghi Ardestani and postdoc Yamila Miguel
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F. Most significant publications of the team

[1] Moutou, C., Deleuil, M., Guillot, T., Baglin, A., Bordé, P., Bouchy, F., Cabrera, J., Csizmadia, S. and Deeg, H. J. "CoRoT: Harvest of the exoplanet program", *Icarus*, vol. 226, pp. 1625-1634
[2] Valencia, D., Guillot, T., Parmentier, V. and Freedman, R. S. "Bulk Composition of GJ 1214b and Other Sub-Neptune Exoplanets", *The Astrophysical Journal*, vol. 775, p. 10 (url) (2013)
[3] Parmentier, V. and Guillot, T. "A non-grey analytical model for irradiated atmospheres. I. Derivation", *Astronomy and Astrophysics*, vol. 562, A133 (url) (2014)
[4] Guillot, T., Santos, N. C., Pont, F., Iro, N., Melo, C. and Ribas, I. "A correlation between the heavy element content of transiting extrasolar planets and the metallicity of their parent stars", *Astronomy and Astrophysics*, vol. 453, pp. id. L21-L24 (url) (2006)

Short CV of participants

Tristan Guillot, is CNRS research director. He is an expert of planetary interiors and planet formation. He is associate Editor of Astronomy & Astrophysics. Author of ~135 reviewed publications, with over 7,700 citations and an H-index of 45 (source ADS), he has been the recipient of the bronze medal of CNRS, of the Urey Prize of the Division for Planetary Sciences of the AAS, and of the Zeldovitch Medal of the Committee for Space Research.