

Exoplanet host-star properties: the active environment of exoplanets

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Abstract. The primary objectives of the ExoplanETS-A project are to: establish new knowledge on exoplanet atmospheres; establish new insight on influence of the host star on the planet atmosphere; disseminate knowledge, using online, web-based platforms. The project, funded under the EU's Horizon-2020 programme, started in January 2018 and has a duration ~ 3 years. We present an overview of the project, the activities concerning the host stars and some early results on the host stars.

Keywords. methods: data analysis, catalogs, stars: activity, stars: atmospheres, stars: coronae, (stars:) planetary systems, stars: winds, outflows, ultraviolet: stars, X-rays: stars

1. Introduction

Seven institutes[†] in Europe have combined their expertise in the field of exoplanetary research to develop the European Horizon-2020 ExoplanETS-A[‡] project under the coordination of CEA Saclay. In the framework of the project, novel data calibration and spectral extraction tools, as well as novel retrieval tools, based on 3D models of exoplanet atmospheres, will be developed to exploit archival data from space- and ground-based observatories, and produce a homogeneous and reliable characterization of the atmospheres of transiting exoplanets. Additionally, to model successfully the exoplanet atmosphere, it is necessary to have a sound knowledge of the host star. To this end, we will collect a coherent and uniform database of the relevant properties of host stars from online archives (e.g. XMM-Newton, Gaia) and publications. These exoplanet and host-star catalogues will be accompanied by computer models to assess the importance

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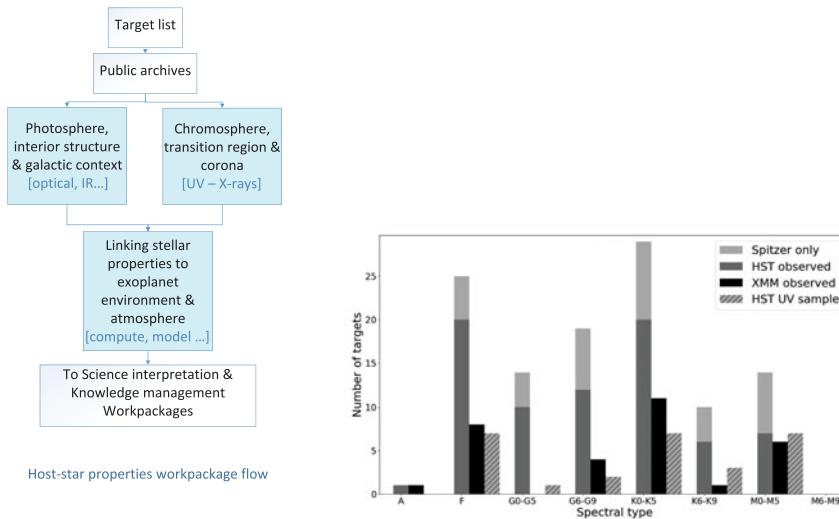


Figure 1. (a, left). Schematic of the flow of data through the host-stars workpackage, and interfaces to the overall project. (b, right). The target sample, in terms of the distribution of host stars with spectral type, showing the breakdown by archival-observation types.

of star–planet interactions, for example the ‘space weather’ effects of the star on its planetary system. The knowledge gained from this project will be published through peer-reviewed scientific journals and modelling tools will be publicly released.

The project has six work packages (WPs); the focus in this paper is on the WP ‘Host-star properties: the active environment of exoplanets’. Fig.1(a) illustrates the flow of data through the host-stars WP, and interfaces to the overall project.

We outline the activities concerning the host stars, and present early results from the host-star investigations, including the basic stellar observational and physical properties, and indications of future observations needed to maximize the coverage of the target list of ~ 100 stars. We also discuss some of the modelling aspects.

2. The host-stars activities

In addition to compiling the observational data, we will where necessary, e.g. in the EUV, interpolate, extrapolate and scale spectral and other information, to cover gaps in the observational data, in order to provide the full XUV spectral range for modelling the host-star influence on the exoplanet atmosphere (e.g. [Nemec et al. 2019](#)). This work will be accompanied by computer models to assess the importance of star–planet interactions, for example the ‘space weather’ effects of the star on its planetary system; We will also model the possible evolutionary scenarios for the stellar activity over the star’s lifetime, in order to gain insight into the past environment of the exoplanet (e.g. [Johnstone et al. 2015](#)).

3. The sample

The sample of exoplanets and host stars considered by the project comprises all transiting-exoplanet systems observed by HST or Spitzer. Currently, this corresponds to 135 exoplanets, of which 85 have HST data; the associated number of stars is 113, with 76 having HST data (Fig.1(b)). For the host stars, the primary online archival databases to be used are HST (for UV spectra), XMM-Newton (for X-ray), Gaia (for astrometric properties) and SIMBAD (for spectral types etc). The searches also include: GALEX

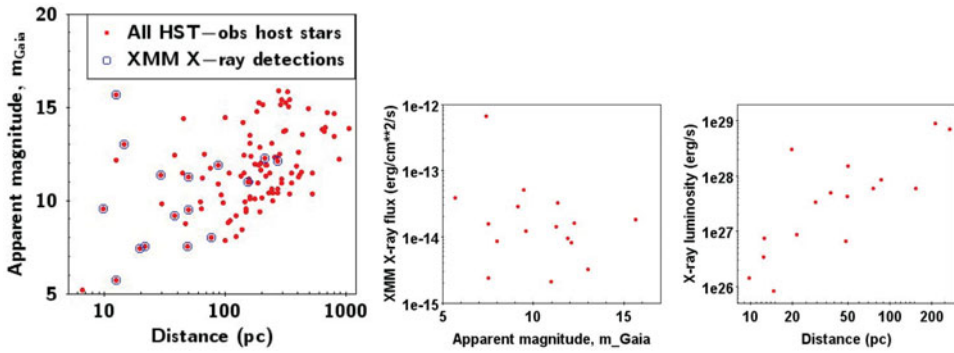


Figure 2. Examples of host-star properties, plotted from the catalogue content.

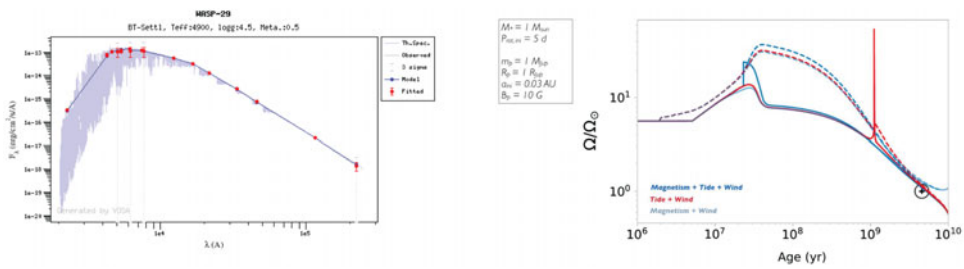


Figure 3. (a, left). SED fitting using VOSA. Blue spectrum represents the theoretical model (Allard *et al.* 2012) that best fits while red dots represent the observed photometry. (b, right). Stellar rotation rate (days) as a function of log(age, years) for 3 cases: wind + Alfvén wings torques (light blue curve), wind + tides (red) and wind + tides + Alfvén wings torques (dark blue) (Ahuir 2018; see Benbakoura *et al.* 2019 for details of the ESPEM code used for the study).

(UV photometry); Chandra, ROSAT and other X-ray catalogues, together with results retrieved from the published literature. At X-ray wavelengths, most of the detections are from the 3XMM (DR8) serendipitous source catalogue (Rosen *et al.* 2016).

In summary, to date (November 2018), we have the following statistics:

- X-ray (3XMM-DR8 cat.): 31 stars observed, with 17 detections in the public archive, and the outcomes awaited for the others;
- UV photometry (GALEX, GR6 cat.): 70 stars detected (51 in the HST sample)
- UV spectra (HST COS and/or STIS): 26 stars observed
- X-ray observation & UV photometry: 23 stars
- X-ray observation & UV spectra: 20 stars

All the stars with XMM observations also have HST visible/IR spectra.

Fig. 2 illustrates a few of the stellar parameters from our initial assessments to date.

In order to fill in gaps in the stellar parameter space (e.g. to have adequate UV and X-ray measurements across spectral types) we are planning observing proposals, principally to HST and XMM-Newton.

4. Determination of the physical parameters of the host stars

A coherent and uniform determination of the stellar properties is essential to avoid any bias in the final results; use of Virtual Observatory (VO) tools facilitates this goal. For example, we have used VOSA (<http://svo2.cab.inta-csic.es/theory/vosa/>) to build observational Spectral Energy Distributions (SED) and compare them with theoretical SEDs (Fig. 3(a)) to obtain physical parameters such as effective temperature, stellar

radius and luminosity. Effective temperatures range from 3000 to 6500K. We have also used VOSA to search for infrared excess in our sources, with negative outcome.

Medium/high resolution spectra for 48 of our sources observed with FEROS, HARPS, FORS 1-2, X-SHOOTER, FLAMES and UVES were gathered from the ESO archive. Visible-light photometry from Kepler/K2 and TESS will also be used to help characterise the stars in terms of rotational and aperiodic variability. One third of our sources have Kepler light-curves while TESS will probably provide data for the remainder.

The ExoplanETS-A database of stellar properties and spectral models will be made publicly available, via a web-based interface, by the end of 2020.

5. Scientific interpretation of the data: star–planet interactions

Most exoplanets live around active stars, whose magnetism and intense activity can have a direct impact on habitability conditions and more generally on the exosphere of the planet. Intense wind and storms can lead to atmospheric loss. Further, a large fraction of exoplanets live close to their host star (within 10–20 solar radii), to a point where in many cases they orbit within the star’s Alfvén surface. This has direct consequence on star–planet interaction and planet migration, as magnetic torques through Alfvén wings directly connecting the planet to its host star can occur. We have developed both ab-initio 3D MHD simulation of such close-in systems (Strugarek *et al.* 2015, Strugarek *et al.* 2017) as well as a simpler 1D secular evolution model of star–planet systems (Benbakoura *et al.* 2019). In Fig.3(b) we show the evolution of a star–planet system subject to intense magnetic torques through direct Alfvén wings connection (on top of tides and wind effect) and compare it to the case with magnetic torques and stellar wind only (light blue curve) or tides + wind (red curve). We note that adding all the effects leads to a quick demise of the planet, that impacts the star’s rotation rate. Such Alfvén wings can also lead to hot spots on the star’s surface, impacting directly their light-curve and hence the transit curves. We intend to develop 3D and secular models for the most important systems identified in the ExoplanETS-A project, as well as obtaining spectropolarimetric magnetic maps of the host star in order to model the stellar wind and assess as accurately as possible the space environment around these exoplanetary systems.

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