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# The Science of ARIEL

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## Abstract

Thousands of exoplanets have now been discovered with a huge range of masses, sizes and orbits: from rocky Earth-size planets to large gas giants grazing the surface of their host star. However, the essential nature of these exoplanets remains largely mysterious: there is no known, discernible pattern linking the presence, size, or orbital parameters of a planet to the nature of its parent star. We have little idea whether the chemistry of a planet is linked to its formation environment, or whether the type of host star drives the physics and chemistry of the planet's birth, and evolution.

Progress with these science questions demands a large, unbiased spectroscopic survey of exoplanets.

The European Space Agency ARIEL M4 candidate mission has been conceived to conduct such a survey and to explore the nature of exoplanet atmospheres and interiors and, through this, the key factors affecting the formation and evolution of planetary systems.

## 1. Introduction

Thousands of exoplanets have now been discovered with a huge range of masses, sizes and orbits: from rocky Earth-like planets to large gas giants grazing the surface of their host star. However, the essential nature of these exoplanets remains largely mysterious: there is no known, discernible pattern linking the presence, size, or orbital parameters of a planet to the nature of its parent star. We have little idea whether the chemistry of a planet is linked to its formation environment, or whether the type of host star drives the physics and chemistry of the planet's birth, and evolution.

## 2. ARIEL mission summary

### 2.1 ARIEL science objectives

ARIEL will observe a large number (~1000) of transiting planets for statistical understanding, including gas giants, Neptunes, super-Earths and Earth-size planets around a range of host star types using transit spectroscopy in the 1.25-7.8 µm spectral range and multiple narrow-band photometry in the optical. We will focus on warm and hot planets to take advantage of their well-mixed atmospheres which should show minimal condensation and sequestration of high-Z materials and thus reveal their bulk and elemental composition (especially C, O, N, S, Si). Observations of these warm/hot exoplanets will allow the understanding of the early stages of planetary and atmospheric formation during the nebular phase and the following few million years. ARIEL will thus provide a truly representative picture of the chemical nature of the exoplanets and relate this directly to the type and chemical environment of the host star [5].

For this ambitious scientific programme, ARIEL is designed as a dedicated survey mission for transit and eclipse spectroscopy, capable of observing a large and well-defined planet sample within its 4-year mission lifetime [1,3]. Transit, eclipse and phase-curve spectroscopy methods, whereby the signal from the star and planet are differentiated using knowledge of the planetary ephemerides, allow us to measure atmospheric signals from the planet at levels of 10-100 part per million (ppm) relative to the star and, given the bright nature of targets, also allows more sophisticated techniques, such as eclipse mapping, to give a deeper insight into the nature of the atmosphere. These types of observations require a specifically designed, stable payload and satellite platform with broad, instantaneous wavelength coverage to detect many molecular species, probe the thermal structure, identify clouds and monitor the stellar activity. The wavelength range proposed covers all the expected major atmospheric gases from e.g. $H_2O$, $CO_2$, $CH_4$ $NH_3$, HCN, $H_2S$ through to the more exotic metallic compounds, such as TiO, VO, and condensed species.

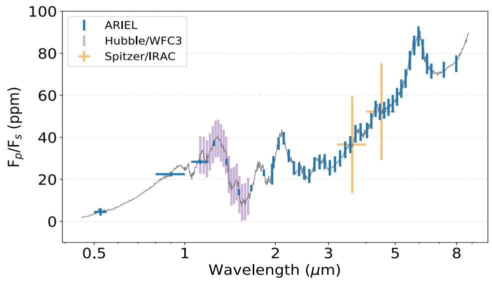


**Figure 1**: Expected output (with error bars) from the ARIEL processed data product compared with the input model assumption for a hot super-Earth similar to 55-Cnc-e around a G-type star with Kmag of 4. ARIEL performances using 8 eclipses (~32 hours of observation) are compared to currently available data for 55 Cnc e from Spitzer-IRAC (8 eclipses, Demory et al., 2016) and performances of Hubble-WFC3 extrapolated from transit observations of 55 Cnc e (Tsiaras et al., 2016).

### 2.2 Performance evaluation

Simulations of ARIEL performance [2,4] in conducting exoplanet surveys have been performed – using conservative estimates of mission performance and a full model of all significant noise sources in the measurement – using a list of potential ARIEL targets that incorporates the latest available exoplanet statistics. The conclusion is that ARIEL – in line with the stated mission objectives – will be able to observe 500-1000 exoplanets depending on the details of the adopted survey strategy, thus confirming the feasibility of the main science objectives [6].

### 2.3 ARIEL data policy

The ARIEL data policy has been designed to embrace the astronomy community in general and the exoplanet community in particular. It is recognised that ARIEL data and data products will be of huge interest to the entire exoplanet community, not only to those directly involved in the mission. The intention is to provide high quality data in a timely manner and to have a continuous dialogue with the wider community, maximising the science that can be achieved by the mission.

## 3. Conclusions

The combination of a stable platform, operating in a stable thermal environment and with a highly integrated payload and systems design, will ensure the very high level of photometric stability required to record exoplanet atmospheric signals, i.e. 10-50 ppm relative to the star (post-processing). The broad, instantaneous wavelength range covered by ARIEL will allow to detect many molecular species, probe the thermal structure, identify/characterize clouds and monitor/correct the stellar activity. Finally, requiring an agile, highly stable platform in L2, from which the complete sky is accessible within a year, will enable the observation of hundreds of planets during the mission lifetime.

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