Exoplanet Characterisation Observatory (EChO)

Assessment Phase Payload Study

The Gaia Survey Contribution to EChO Target Selection and Characterization

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PREAMBLE

1.1 SCOPE

This document covers the realm of the expected contribution of the Gaia mission catalogue data towards the selection and characterization of the EChO target sample.

1.2 PURPOSE

The purpose of this document is to what elements of the Gaia catalogue will be of utmost relevance for the selection and characterization of transiting planet systems to be observed by EChO

1.3 APPLICABLE DOCUMENTS

AD #	APPLICABLE DOCUMENT TITLE	DOCUMENT ID	ISSUE / DATE
1			
2			
3			

1.4 REFERENCE DOCUMENTS

RD #	REFERENCE DOCUMENT TITLE	DOCUMENT ID	ISSUE / DATE
1			
2			
3			

2 INTRODUCTION

Gaia (e.g., Lindegren 2010), due to launch in October 2013, in its five-year all-sky astrometric survey will deliver direct parallax estimates for nearby main-sequence stars down to the broadband G=20 mag limit of the survey. At V=15 mag, typical F-G-K dwarfs within 0.5 kpc from the Sun will have parallaxes measured to better than 1-2% accuracy. Distances to relatively bright (K < 10) early- to late-M stars out to 20-30 pc will be known with better than 0.1%-1% precision (depending on spectral sub-type). This will constitute an improvement of up to over a factor 100 with respect to the typical 25%-30% uncertainties in the distance reported for low-mass stars identified as nearby based on proper-motion and color selections (e.g., Lepine 2005; Lepine & Gaidos 2011).

Furthermore, Gaia is equipped with two low resolution prism spectrophotometers which together provide the spectral energy distribution (SED) of all targets from 330–1050 nm, with a resolution varying between 13 and 85. The main purpose of these spectrophotometers (named BP and RP, for “blue photometer” and “red photometer”) is to classify the objects (into star, galaxy, quasar etc.) and to determine the stars’ physical properties (as well as to provide a chromaticity correction for the astrometric data analysis). For stars at G=15 with less than two magnitudes of extinction, the expectation is that based solely of the Bp/RP spectra it will be possible to estimate T_{eff} to within 1%, log(g) to 0.1–0.2 dex, and [Fe/H] (for FGKM stars) to 0.1–0.2 dex (Liu et al. 2012).

Finally, the single-field-of-view-transit photometric standard errors of the integrated G-band (Jordi et al. 2010) will remain below 1 mmag for V < 13. At V=15, they are expected to be on the order of 2 mmag, with only a weak color-dependence. The G-band data will be of particular use for stellar variability studies.

3 PLANET HOSTS CHARACTERIZATION

Starting with early data releases around mid-mission (astrometric parameters for most of Gaia stars will be made available as early as 28 months after mission launch, in mid-2016), the Gaia exquisitely precise distance estimates, and thus absolute luminosities, to nearby late-type stars will allow to improve significantly standard stellar evolution models at the bottom of the main sequence. For transiting planet systems, updated values of masses and radii of the host stars will be of critical importance. Model predictions for the radii of M dwarfs show today typical discrepancies of ~15% with respect to observations, and as shown by the GJ 1214b example (Charbonneau et al. 2009) limits in the knowledge of the stellar properties significantly hamper the understanding of the relevant physical characteristics (density, thus internal structure and composition) of the detected planets. With Gaia, stellar radii for this sample are expected to be measured to within 2-3% precision. However, the impact of Gaia parallaxes will be very relevant also for improved characterization of most of the F-,G- and K-type transiting planet hosts presently in the target list of EChO, the vast majority of them lacking a direct distance estimate (Note that final parallax estimates will be made available to the scientific community in the global Gaia catalogue 1 year prior to EChO's nominal launch date).

In order to obtain precise radii estimates (a derived quantity), an approach similar to that described by Bailer-Jones (2002) will be adopted. In particular, the high-SNR (~200) spectral energy distributions from the BP/RP spectra for bright (V<15), not heavily reddened stars will allow, in combination with the exquisitely precise parallaxes, to obtain accurate (to a few percent) absolute luminosities. Provided the effective temperature estimates can be precise to

1% (feasible for bright stars, see Liu et al. 2012), then, for the solar-type stellar sample targeted by ECho, the expectation is for a determination of stellar radii to better than 3% precision. A summary of the process to derive stellar radii using Gaia data is given in Figure 1. In the eventuality that the SNR of Gaia observations were to be reduced for a given star, thus not allowing to achieve the required precision on T_{eff} determinations, it is worth mentioning how all the presently confirmed transiting planets have been observed with high-resolution spectrographs at 4-10m telescopes, thus the objective can also be achieved by combining the

non-astrometric parametrizer:

nSED, (RVS)	$\Rightarrow$	$T_{\rm eff}$, $\log g$, [Fe/H],	
		A_λ, BC, $[\alpha/\mathrm{Fe}]$?	atmospheric model

additional use of astrometry gives:

SED, BC, π, A_λ	$\Rightarrow$	L	$2.5 \log L - f(\mathrm{SED}, \mathrm{BC}) = A - 5 \log \pi$
L, $T_{\rm eff}$	$\Rightarrow$	R	$L = 4\pi R^2 \sigma T_{\rm eff}^4$

Figure 1: Stellar parameters derivable from the Gaia data. SED=spectral energy distribution (spectrophotometric measurements in medium and broad band filters); nSED=normalized SED (absolute flux information removed); RVS=radial velocity spectrum; BC=bolometric correction; π=parallax; A_λ=interstellar extinction function. From Table 1 in Bailer-Jones (2002).

absolute luminosity estimates from Gaia with effective temperature determinations using ground-based high-resolution spectroscopy.

In summary, the wealth of Gaia data holds promise to significantly reduce (if not outrightly eliminate) one major source of potential confusion in atmospheric characterization measurements of transiting exoplanets carried out by EChO. The both accurate and precise knowledge of stellar radii will translate in more accurate and precise planetary radii. As a result, the more precisely determined planetary densities will allow for significantly reduced uncertainties in the inferred compositions. In turn, these results will crucially inform any atmospheric characterization measurements with EChO, particularly when it comes to super-Earths, for which, degeneracies in the models of their physical structure indicate a wide range of possible compositions for similar masses and radii (Seager & Deming 2010, and references therein)

4 TARGET SELECTION

Gaia will be capable of measuring accurate astrometric orbits and masses for giant planets within approximately 0.3-4 AU of moderately bright (6<V<13 mag, with current attempts at pushing the bright limit down to V~2-3 mag) F-G-K stars out to ~200 pc from the Sun (Casertano et al. 2008). The Gaia potential for detection and characterization of giant planets orbiting the reservoir of thousands of nearby low-mass M dwarfs within a ~30 pc from the Sun is presented in detail in Sozzetti et al. (2013). The Gaia contribution to the EChO target list in terms of actual transiting (and non-transiting) exoplanets detected astrometrically is described in detail in the Technical Note “Role of the major planet search surveys to EChO targets” (REF

CODE). We focus here on two further elements of information provided by Gaia that can contribute to the optimal selection of EChO targets.

1) ALL known transiting planet systems of potential interest for EChO will be probed by Gaia to find evidence for outer companions (massive giant planets, brown dwarfs, and very low-mass stars) in at least three ways. First, Gaia will be capable of detecting astrometrically wide-separation faint companions (giant planets and brown dwarfs) by measuring significant acceleration terms in the proper motion. Second, brighter, unresolved companions (low-mass stars) might be recognized as 'variability induced movers' in Gaia astrometry. Third, Gaia might possibly directly (or partly) resolve existing wide-separation (> 1 arcsec) companions down to the G=20 mag survey limit. Combining the Gaia data with the available information from long-term radial-velocity monitoring and direct imaging, it will thus be possible to characterize the neighbourhood of each transiting planet host in order to identify any extremely red objects that, being quite bright at 5-15 μm, might complicate the interpretation of EChO's atmospheric characterization measurements.

2) While the predefined Gaia scanning law will not allow to carry out intensive photometric monitoring of the potential EChO target sample, the mission will still deliver typical per-measurement precision of ~1 mmag at the relatively bright magnitudes of interest for EChO. Particularly for targets observed more frequently by Gaia (with, e.g., > 100 measurements during five-years nominal mission duration), it will thus be possible to combine Gaia photometric data with existing ground-based and space-borne (e.g., CHEOPS) photometry in order to characterize the various timescales of microvariability of the reservoir of potential EChO targets using a time baseline on the order of two decades.

The two abovementioned issues are now a matter of a quantitative assessment study within the framework of 'Targets' and 'Synergies with Other Facilities' Working Groups.

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