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Supporting Observations for EChO

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1 INTRODUCTION

The purpose of this document is to summarize the various supporting and ancillary observations that should/could be carried out to optimize the science return of the EChO mission. These include various efforts to characterize the host stars and their planetary system as a whole, and long-term monitoring of the host stars contemporaneously with EChO observations to better constrain their variability.

2 PRECISE HOST STAR PARAMETERS

A precise knowledge of the host star fundamental parameters is important for EChO. Stellar radius in particular directly impacts the derived planetary radius, and thus has an influence on the physical scaling of the exoplanet transmission spectrum and the physical interpretation of the exoplanet emission spectrum. Other relevant stellar parameters include stellar mass, age, luminosity, effective temperature, metallicity, and abundances of various individual elements. We provide below an overview of the methods and instruments that will be used to measure these properties to a precision that is sufficient to make stellar parameters only a minor contributor to the overall error budget in EChO spectra.

Distance, luminosity, effective temperature, radius: The most accurate path towards these parameters will make use of the ultra-precise GAIA parallaxes and measured spectral energy distributions (SEDs) of the targets. SEDs will come both from GAIA, and from EChO itself. Provided an absolute flux calibration for EChO can be obtained at the few percent level over the broad wavelength range of EChO, the obtained SEDs combined to the GAIA distances will yield the luminosity, effective temperature and radius of the target to unprecedented accuracy (see Technical Note by A. Sozzetti). Effective temperature can also be measured through ground-based high-resolution spectroscopy. While this method works well for solar-type stars, it is expected to be less accurate for late-K and M stars. Stellar radius can also be measured directly through long-baseline interferometry, using instruments like CHARA, VLTI-PIONIER and the MRO interferometer. The number of EChO targets that will be accessible to this technique is unclear, however.

Mass: This fundamental property can only be derived through comparisons with stellar evolution models. Given accurate luminosity, effective temperature, radius and metallicity, the derived mass of EChO targets will be tightly constrained.

Metallicity, chemical abundances: High-resolution spectroscopy of essentially all EChO targets will be available through the Doppler monitoring programs aiming at measuring the planet mass (HARPS, HARPS-N, ESPRESSO, Keck/HIRES, SOPHIE, CARMENES, SPiROU, etc). Metallicity and abundances of various elements can be determined from these data.

Activity level, rotation period: High-resolution spectroscopy from Doppler surveys will also yield measurements of stellar activity levels, in particular the Ca II H & K chromospheric emission index log(R'HK) and H-alpha emission. Stellar rotation periods can be estimated from these data through an activity-rotation calibration, although with relatively large error bars for individual objects. We note here that the presence of a close-in giant planet may influence the rotational and activity evolution of a star, and therefore make the estimated rotation periods unreliable. Fortunately, time series of log(R'HK) or H-alpha measurements can provide the rotation period directly, from the modulations caused by rotating active regions on the star. This is also achievable with broadband ground-based photometry, provided rotational variability is at a level of at least a few mmag.

Age: This fundamental property can only be obtained indirectly, either through stellar evolutionary models, gyrochronology (rotation-age calibration), or asteroseismology. However, models are sensitive probes only in the regions of the HR diagram where stellar evolution is fast, i.e. at young ages or at the end of the main sequence lifetime. Gyrochronology gives population-wide relations between rotation period and age, but may fail to give accurate ages for individual objects. Asteroseismology (coupled to stellar models) is potentially the most accurate technique but is demanding in terms of observational effort: long, uninterrupted time series of high-precision photometric or spectroscopic measurements are needed. The TESS mission may be able to constrain the ages of EChO targets through this technique. Overall, stellar age is probably the most difficult parameter to accurately measure, except for young stars (< 1 Gyr) or stars leaving the main sequence.

3 HOST STAR MULTIPLICITY

Stellar binarity and multiplicity is likely to play a significant role in shaping planetary systems, e.g. through its impact on protoplanetary disks or Kozai dynamical perturbations. Knowledge about stellar companions to EChO targets is therefore important and make it possible to search for correlations between planetary structure/composition and host star environment in order to study planet formation processes. Companions to EChO targets can be searched for by different techniques, depending on the separation between components. The available Doppler velocimetry of EChO targets will detect or constrain the presence of relatively close stellar companions (< 10-100 AU) provided a time baseline of several years can be obtained. Direct imaging using adaptive optics systems (e.g. VLT-SPHERE, Gemini-GPI, Subaru-SCExAO, Magellan-MagAO) will probe the outer regions of the systems and reach as close as a few AUs to the host star, depending on their distance. And most importantly, GAIA will detect all stellar companions in a broad separation range

(0.3-100 AU, depending on distance) and will thus be the main source of information for multiplicity studies of EChO targets.

Finally, we note that the knowledge about potential stellar companions around EChO targets will be important also for the analysis of EChO spectra. Possible contamination by the light of the companion across the broad EChO wavelength range has to be taken into account for proper derivation of the exoplanet spectrum.

4 PROPERTIES OF HOST PLANETARY SYSTEMS

Similarly to stellar multiplicity, knowledge of the number and mass of planets within the planetary system and their dynamical architecture is likely to be an important ingredient to improve our understanding of planet formation mechanisms and interpret the EChO findings. Identifying all dynamically relevant planets in a system is a challenging task from an observational point of view, but several techniques are available to explore the inner and outer regions of the EChO systems with sensitivities reaching down to 1-10 Earth masses.

Transit photometry: if other planets in the system are transiting besides the EChO target itself, a wealth of information can be obtained with high-precision photometry: orbital parameters, planet radius, and atmospheric characterization with EChO itself, obviously. Planet mass can be obtained through Doppler follow-up, as usual. The precise geometrical alignment required to have multiple transiting planets in a system makes this case rather rare, however, although the TESS and CHEOPS missions will probably find a number of such systems that would make very compelling EChO targets (note that Kepler has indeed found many multi-transiting planetary systems).

Doppler velocimetry: Radial velocity planet search programs are able to detect all planets in a system that are above the specific mass vs. semi-major axis limit of the survey. For EChO systems where at least one planet is transiting, the inclination angle of all planetary orbits is likely to be close to 90° (i.e. $\sin i = 1$), except perhaps in systems with misaligned hot Jupiters. In most cases one can then expect that Doppler velocimetry will yield minimum masses that are close to true masses. As an example, RV observations will be able to study the presence and orbital properties of additional giant planets in hot Jupiter systems, or the number and properties of additional Neptunes and super-Earths in compact, close-in systems, which are now known to be very common.

GAIA astrometry: GAIA will again play an important role, mainly for the exploration of the intermediate regions of the planetary systems observed by EChO. Almost all giant planets in the 0.5-5 AU range will have been detected by GAIA, which will measure their masses and orbital parameters (see Technical Note by A. Sozzetti).

5 LONG-TERM STELLAR ACTIVITY MONITORING

Stellar activity may induce various biases in the derived exoplanet spectra obtained by transit and occultation spectroscopy. In particular, inhomogeneities on the stellar photosphere can alter the shape of the primary transit of an exoplanet. In the case of unocculted star spots, the stellar brightness appears dimmer than a spotless photosphere, and the measured transit depth is consequently increased. On the other hand, if the planet disk crosses a star spot along the transit chord, a localized increase in flux will appear in the lightcurve and the measured transit depth will be biased towards lower values. Since star spots have different effective temperatures than the stellar photosphere, their effects on the transit lightcurve vary as a function of wavelength and therefore impact the global shape of the transmission spectrum.

The importance of modelling stellar activity has been recognized early in the EChO project and has led to specific science requirements. In particular, the wavelength coverage of EChO will extend up to 0.55 micron in the visible (goal: 0.4 micron) to better constrain the presence and properties of star spots and active regions.

In addition to the precise spectrophotometric information that can be extracted from the EChO data themselves, it may be useful to complement them with long-term, ground-based monitoring of stellar activity. The temporal coverage of the EChO data will be limited to the observed transit/occultation windows. Since proper modelling of activity involves many free parameters, it may be necessary to have a more complete time baseline to understand the properties and evolution of active regions on the star. Most useful would be observations that cover the time window from the first to the last event observed by EChO on a given target. The monitoring cadence should be adapted to each target to have a suitable sampling of the stellar rotation period (days to months) and of long-term magnetic cycles (years to decades).

Two types of ground-based observations can be envisaged: broadband photometric monitoring and spectroscopic monitoring of chromospheric emission lines such as CaII H&K. The former can be carried out by small robotic telescopes equipped with standard CCD imagers that would jump from one EChO target to the next in a sequential way and be able to obtain precise photometry of several tens of objects per night. The latter can be obtained by high-resolution spectrographs on larger telescopes (e.g. CORALIE/HARPS). In this case dedicated observing programs would be needed. Note that the major RV surveys already monitor the CaII H&K activity index by construction, since the same spectra used for RV computation also cover the CaII H&K lines.

It is difficult to quantify at this stage to what extent such monitoring programs contemporaneous with EChO observations are necessary to fully exploit the potential of EChO. However, it is important to note that facilities able to carry out both the photometric and spectroscopic monitoring already exist today, and that there are no major technical challenges to overcome to implement such programs. It is important to better quantify the needs of EChO regarding stellar activity in the next phases of the project to eventually make a decision on potential ground-based monitoring programs.

6 REFERENCES

Sozzetti A., et al. 2013, "The GAIA Survey Contribution to EChO Target Selection and Characterisation", ECHO-TN-0001-OATO