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Photometric stability analysis of the Exoplanet Characterisation Observatory (EChO)

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Abstract

The science of extrasolar planets is one of the most rapidly changing areas of astrophysics and since 1995 the number of planets known has increased by almost two orders of magnitude. A combination of ground-based surveys and dedicated space missions has resulted in 800-plus planets being detected, and over 2000 that await confirmation. NASA's Kepler mission has opened up the possibility of discovering Earth-like planets in the habitable zone around some of the 100,000 stars it is surveying during its 3 to 4-year lifetime. The new ESA's Gaia mission is expected to discover thousands of new planets around stars within 200 parsecs of the Sun. The key challenge now is moving on from discovery, important though that remains, to characterisation: what are these planets actually like, and why are they as they are? The Exoplanet Characterisation Observatory (EChO) is a space mission dedicated to undertaking spectroscopy of transiting exoplanets over the widest range possible. In the frame of ESA's Cosmic Vision programme, the Exoplanet Characterisation Observatory (EChO) has been considered as medium- sized M3 mission candidate for launch in the 2022 - 2024 timeframe [3]. The current 'Phase-A study' space-mission concept is a 1.2 metre class telescope, passively cooled to $\sim$50 K and orbiting around the second Lagrangian Point (L2). The current baseline for the payload consists of four integrated spectrographs providing continuous spectral coverage from 0.5 - 16μm at resolution ranging from R $\sim$ 300 to 30.

1 Photometric Stability

EChO will observe the spectra of transiting exoplanets using time-resolved spectroscopy, following the transit or the eclipse with a set of highly stable spectographs. The stability of the instrument is hence paramount to the success of the mission. In [4] we investigate the impact of potential photometric instability sources and their impact on the retrievable science.

In this poster and [4] we classify the photometric stability into three categories

1. *Pointing stability of the telescope:*
   The 1σ pointing jitter of the satellite is currently base-lined to be of the order of 10 milli-arcsec from 90s to 10h of continuous observation[1]. These pointing drifts manifest themselves in the observed data product via two mechanisms: 'spectral jitter' and 'spatial jitter' along the spectral and spatial axes; 2) 'spatial jitter'. The effect of pointing jitter on the observed time series manifests as non-Gaussian noise correlated among all detectors in all focal planes of the payload and is characterised by the power-spectrum of the telescope pointing.

2. *Thermal stability of the optical-bench and mirrors:*
   Fluctuations in thermal emissions constitute a source of correlated noise in the observations and need to be maintained at amplitudes small compared to the science signal observed. Given a $\sim$45K (the currently baselined temperature) black-body peaks in the far-IR, we are dominated

[1] ESA report: EIDA-R-0470

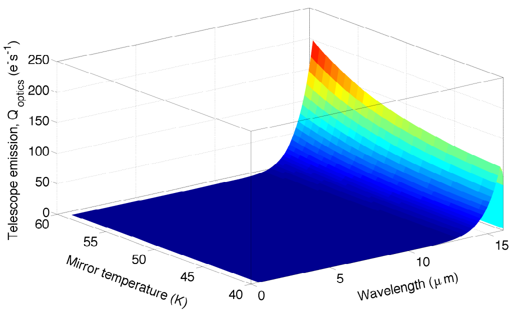

Figure 1: Detector counts (in e-/s) due to the telescope emission, as a function of temperature and wavelength.

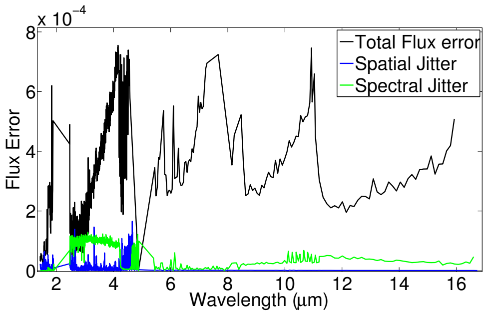

Figure 2: Error budget per wavelength in terms of planetary contrast ratio of HD189733b. Red: total flux error; blue: spectral jitter, green: spatial jitter.

by the Wien tail of the black body distribution, resulting in steep temperature gradients and stringent requirements on thermal stability in the long wavelength instruments.

3. *Stellar noise and other temporal noise sources:* Whilst beyond the control of the instrument design, stellar noise is an important source of temporal instability in exoplanetary time series measurements [1]. This is particularly true for M dwarf host stars as well as many non-main sequence stars.

2 Methodology

To investigate the impact of telescope jitter and thermal fluctuations of the instrument on the science we use the end-to-end simulator EChOSim [**?**]. This simulator allows for an efficient mapping of the possible parameter space for the instrument and allows the overall noise budget to be calculated (see figures as examples of the current outputs).

3 Summary

we present the methodology used for a photometric stability analysis of the EChO mission and asses the photometric stability given its current ‘Phase-A’ design specifications. We describe how spectral and spatial jitter due to space-craft pointing uncertainties are propagated to an uncertainty on the exoplanetary spectrum measured by EChO. We furthermore investigate tolerances on the thermal stability of the space-craft’s optical path.

Acknowledgments

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References

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[4] Waldmann, I. P., Pascale, E., Swinyard, B., MNRAS submitted