Exoplanet Characterisation Observatory (EChO)

Assessment Phase Payload Study

Evaluation of Science Impact of Reduced LWIR Resolution

ECHO-TN-0002-OXF

Issue 1.0

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Checked / Approved by: Neil Bowles Date: 11/9/13

DOCUMENT CHANGE DETAILS

Issue	Date	Page	Description Of Change	Comment

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1 PREAMBLE

1.1 SCOPE

This document briefly summarises the case for including the LWIR channel if the sensitivity of the available infrared detectors are not compatible with the resolving power of R=30 described in the EChO Mission Requirements Document (MRD, RD1). Calculations based on radiative transfer/inverse models show that for resolving powers as low as R=10 the 11–16 μm band can still make a significant contribution to EChO's science goals.

1.2 PURPOSE

This document supports the inclusion of the goal 11–16 micron wavelength instrument on the EChO space telescope at resolving powers lower than R=30 described in RD1.

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	EChO Mission Requirements Document	SRE-PA/2011.038	3.0
2	EChO Atmospheric Retrieval Technical Note	ECHO-TN-0001-OXF	1.0
3			

1 INTRODUCTION

The baseline wavelength range for EChO extends to 11 microns, with a goal to include an 11–16 micron channel. Detector options may limit the achievable resolving power for this channel, but there is still useful information to be gained from including an 11–16 micron channel with a comparatively low (R<10) spectral resolving power or a few (~5) photometric points. This document briefly summarises the science case for including an instrument capable of measuring radiances at ~5 spectral points within the 11–16 micron range. See also the EChO retrieval technical note RD2 for further details of the radiative transfer and spectral inversion procedures referred to.

2 OUTLINE SCIENCE CASE FOR 11–16 MICRONS AT RESOLVING POWERS OF R<30

2.1 WARM JUPITER

For hot Jupiters, there is sufficient signal in thermal emission spectra at shorter wavelengths such that their atmospheric properties can be inferred without measurements at wavelengths longer than 11 microns. However, cooler planets emit at longer wavelengths. For a warm Jupiter (equilibrium temp ~650 K) orbiting a sun-like star 35 pc away, we would need to observe at least 30 eclipses to retrieve the temperature structure and abundances of trace species H_2O, CO_2, CO, CH_4 and NH_3 from the planet/star flux ratio spectrum (Barstow et al. 2013a). We repeat the analysis of Barstow et al. 2013a for this case, including only wavelengths up to 11 microns and then testing the effect of also including 4 broadband points up to 16 microns. We find that observations up to 11 microns can provide good constraints on the temperature profile between 0.001 and 1 bar, and can also result in an accurate retrieval of H_2O, CO and NH_3 abundances; however, CO_2 and CH_4 are not correctly retrieved to within 1σ error. If instead four broadband points (width 1.4 microns) between 11 and 16 microns are also included, we find that the temperature below 1 bar, CO_2 abundance and CH_4 can now also be correctly retrieved (Figure 1, Table 1). This is good evidence that, even at low resolving power, the 11–16 micron wavelength range provides important information about the atmospheres of cooler exoplanets, and its inclusion as part of EChO is strongly encouraged.

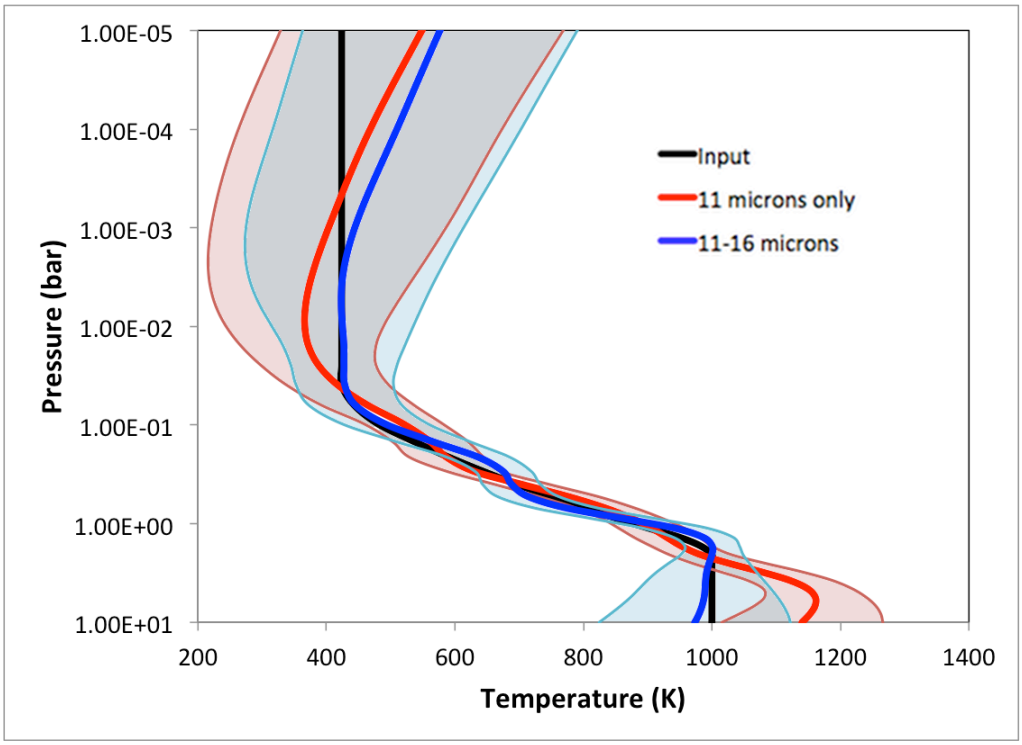

Figure 1: Temperature retrievals for 30 transits of a warm Jupiter orbiting a sun-like star if different spectral ranges are observed. It can be seen that including 11–16 microns improves the quality of the temperature retrieval in the deep atmosphere. The shaded regions indicate the 1σ error on the temperature retrievals.

	Input (100 ppmv)	Retrieved (11 microns)	Retrieved (11–16 microns)
H_2O	0.02573	0.0221-0.0375 (0.0288)	0.0221-0.0392 (0.0294)
CO_2	0.1957	0.239-0.492 (0.343)	0.195-0.319 (0.250)
CO	2.871	1.81-3.24 (2.42)	2.21-4.17 (3.04)
CH_4	0.1342	0.135-0.187 (0.159)	0.127-0.173 (0.148)
NH_3	0.8691	0.794-1.37 (1.04)	0.803-1.31 (1.03)

Table 1: Retrieved trace gas abundances (volume mixing ratios in 100 ppmv) compared with the input. The +/-1σ range is given for the retrievals, with the best-fit value in parentheses. CO_2 and CH_4 VMRs are not retrieved correctly to within 1σ error if the long wavelength cut off is at 11 microns, but including up to 16 microns results in a correct retrieval for all gases.

2.2 GJ 1214B

Another key target for EChO is the warm super-Earth GJ 1214b. With an equilibrium temperature of only ~500 K, there are currently no observatories with the capability to observe its emission spectrum. EChO could detect a thermal emission signal from this planet for wavelengths greater than 5 microns, by observing and averaging over 30 transits. A measurement of stratospheric temperature from eclipse observations will be necessary to break model degeneracies between bulk atmospheric composition, cloud optical depth and temperature in analysis of transmission spectra (Barstow et al. 2013b). In Figure 2, we show the added information about the atmospheric temperature structure gained from including the 4 extra broadband points in the 11–16 micron wavelength range.

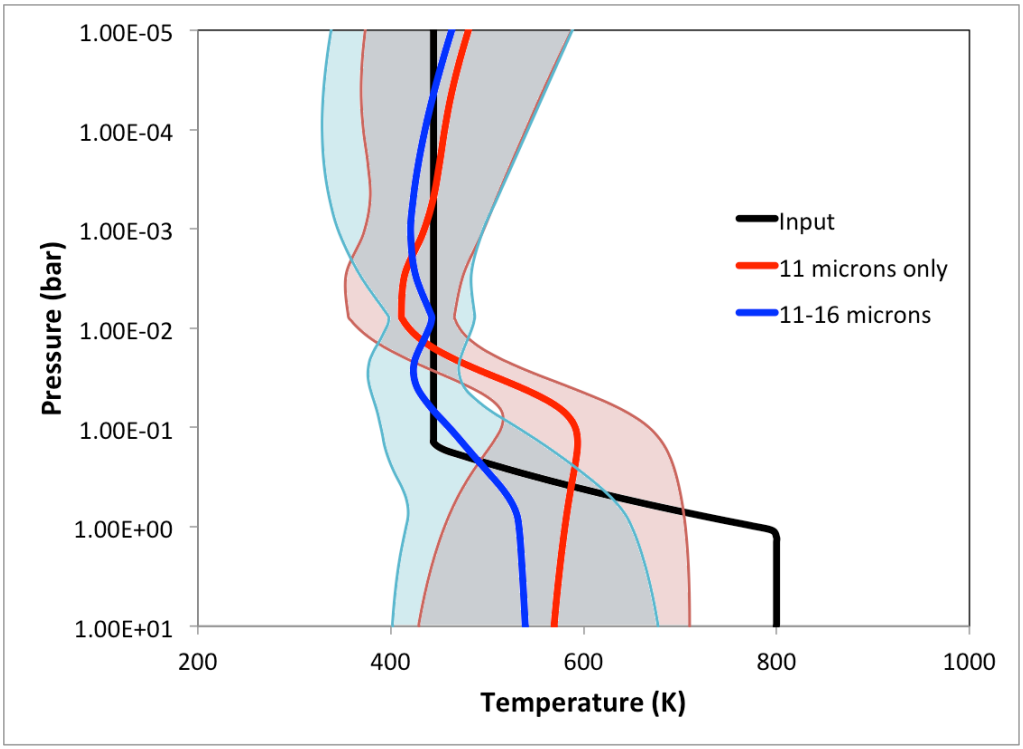

Figure 2: Temperature retrievals for 30 transits of GJ 1214b if different spectral ranges are observed. It can be seen that including 11–16 microns improves the quality of the temperature retrieval at the tropopause. The shaded regions indicate the 1σ error on the temperature retrievals.

3 SUMMARY

We conclude that the inclusion of four broadband photometry points in the 11–16 micron range adds valuable information about the thermal structure and atmospheric composition of warm Jupiters and super-Earths. This spectral range should therefore form part of EChO if possible.

4 REFERENCES

Barstow J. K., Aigrain S., Irwin P. G. J., Bowles N., Fletcher L. N., Lee J.-M., 2013, MNRAS, 430, 1188

Barstow J. K., Aigrain S., Irwin P. G. J., Fletcher L. N., Lee J.-M., 2013, MNRAS, 434, 2616