Exoplanet Characterisation Observatory (EChO)

Assessment Phase Payload Study

NH3 detectability: 11 µm vs 10.6 µm cutoff

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NH_3 detectability: 11 µm vs 10.6 µm cutoff

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In this Tech Note we investigate the impact of a potential degradation of the instrument's performances at the edge of the EChO required spectral interval, i. e. 11 µm.
Among the key molecules detectable by EChO, ammonia (NH_3) is the only one having a strong absorption feature close to 11 µm. The centre of this band is at ~ 10.5µm but the wings extend between 10µm and 11.2µm. Other strong NH_3 bands occur close to 3µm and 6.1µm: these are more easily detectable for warm and hot planets.

Ammonia is expected to be present in hydrogen rich atmospheres, with mixing ratios between ~10^{-5} and 10^{-7} (Moses et al., 2011; Venot et al., 2012,2013). We adopt here the test case of a Warm Neptune, and we use a likelihood ratio test to compare the molecular detectability for different instrument cut-offs. We repeat the experiment also with a simpler and more intuitive method (bin by bin).

Likelihood Ratio Test

This method is described in Tessenyi et al 2013.

1. The results presented in the paper showed NH_3 detectability (> 3 sigma) for a mixing ratio = 10^{-7}, over the 1 to 16µm range (EChO goal spectral coverage).

2. Switching to 1 to 11 µm range (required spectral coverage), the detection confidence decreases but it is still > 3 sigma.

3. Switching to 1 to 10.6 μm range, there is only a marginal difference in the detection confidence compared to 2.

Figures 1, 2 and 3 below show the 1 to 16μm, 1 to 11μm and 1 to 10.6μm cases respectively.

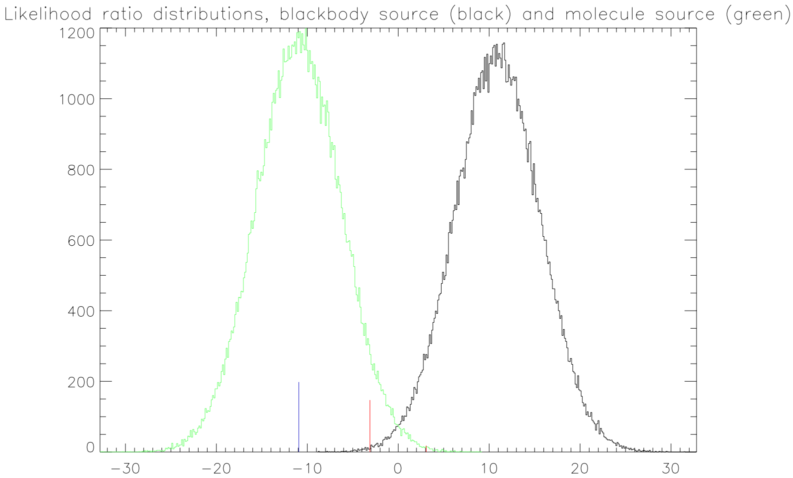

Figure 1: Likelihood ratio distributions for the 1 to 16μm case of NH_3 at abundance 10^{-7} in the atmosphere of a Warm Neptune. The detectability is > 3 sigma (see Tessenyi et al 2013 Methods)

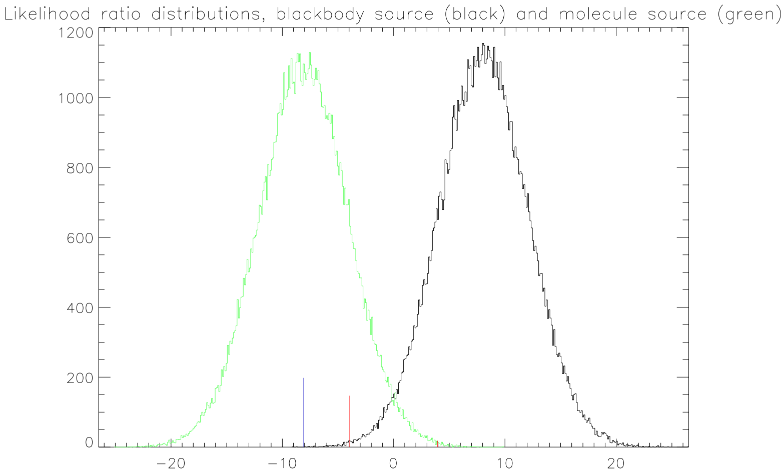

Figure 2: Likelihood ratio distributions for the 1 to 11μm case of NH_3 at abundance 10^{-7} in the atmosphere of a Warm Neptune. Although the distributions are less well separated, the detectability is still > 3 sigma (see Tessenyi et al 2013 Methods)

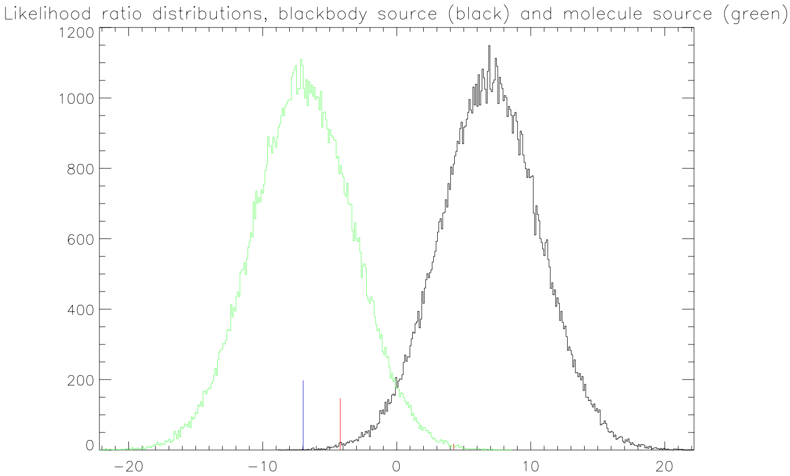

Figure 3: Likelihood ratio distributions for the 1 to 10.6μm case of NH_3 at abundance 10^{-7} in the atmosphere of a Warm Neptune. The distributions appear closer than in Figure 2, but the detectability is still > 3 sigma (see Tessenyi et al 2013 Methods)

The same exercise has been repeated for a larger mixing ratio, i.e. 10^{-5}.

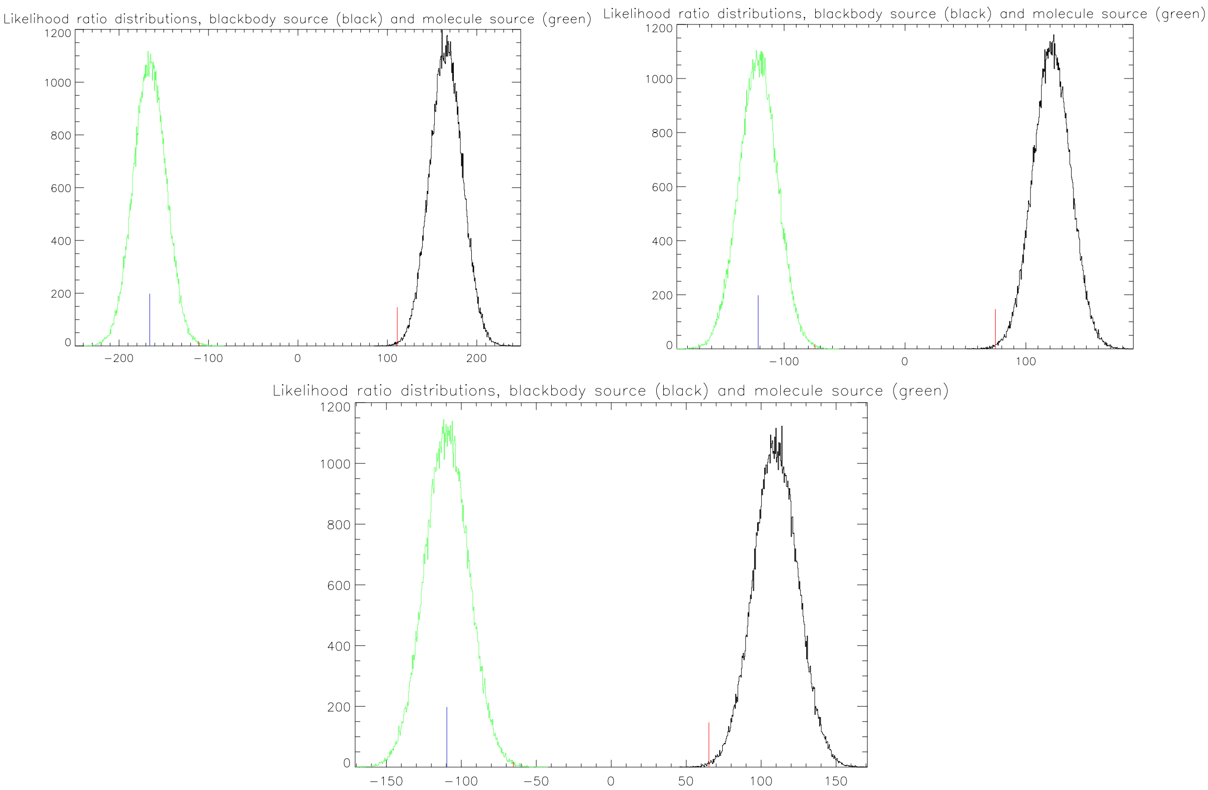

Figure 4: Likelihood ratio distributions for the 1 to 16μm (top, left), 1 to 11μm (top, right) and 1 to 10.6m (bottom) cases of NH_3 at abundance 10^{-5} in the atmosphere of a Warm Neptune. As the wavelength range is shortened, the distributions are closer together. In all cases the detection is very strong.

Bin-by-bin Method

This method is described in Tessenyi et al 2013 and it is used here to test whether a cut-off at 10.6 μm rather than 11 μm, would impact on the scientific results. We adopted these parameters:

- SNR=5, NH_3 mixing ratio = 10^{-5}
- SNR=10, NH_3 mixing ratio = 10^{-6}
- SNR=20, NH_3 mixing ratio = 10^{-7}

For the sake of simplicity, our simulations are shown at a fixed SNR (Figs 5, 6, 7). For all the three cases there is at least one bin with a 3 sigma detection between 10 and 10.6μm. This is not the case between 10.6 and 11μm

a) SNR=5

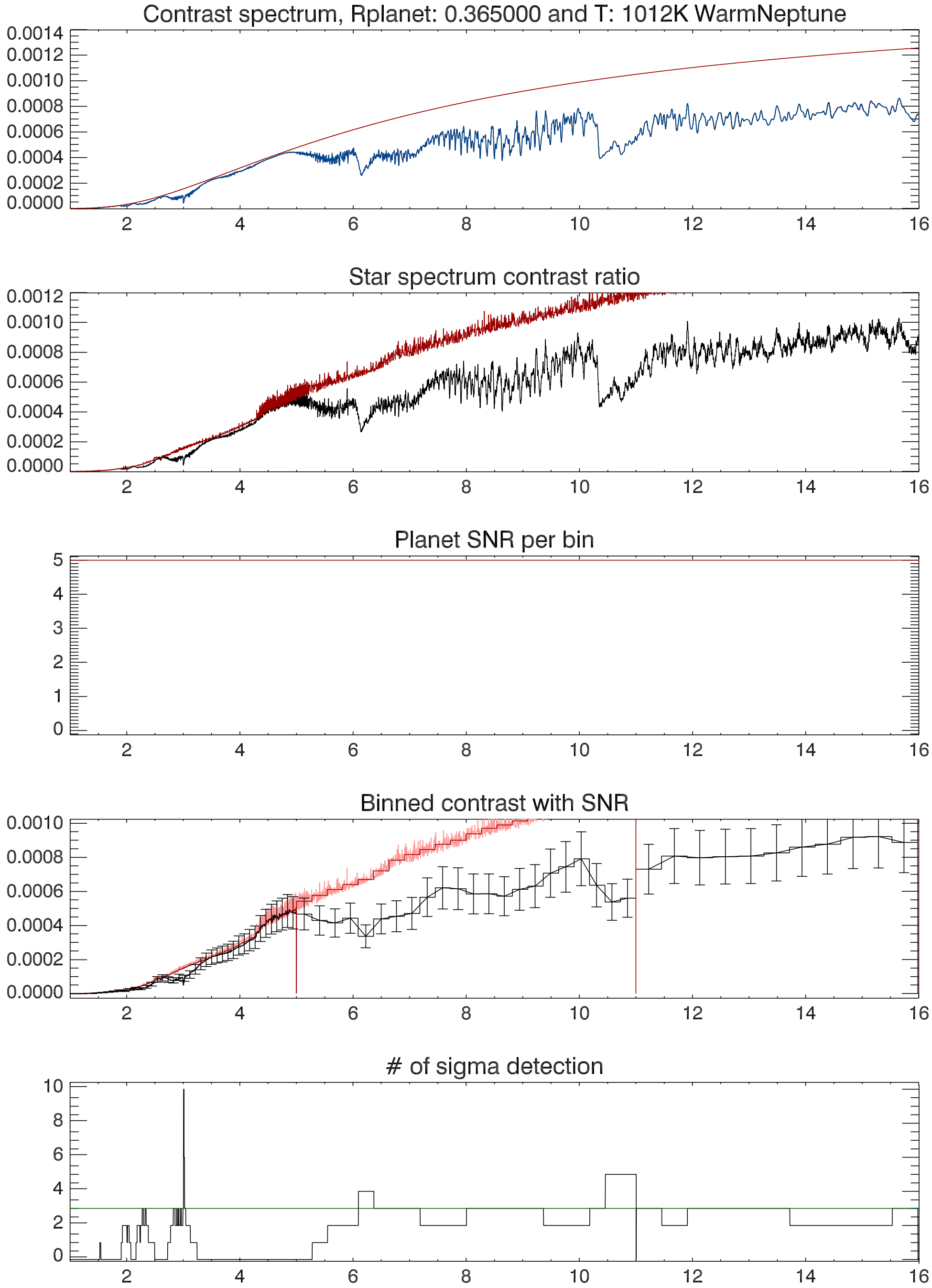

Figure 5: Fixed SNR bin-by-bin detectability method for a Warm Neptune, at SNR=5 and abundance 10^{-5}. The first diagram shows the planet/star contrast spectrum, where the star is a simulated blackbody. The second diagram is the same planet spectrum but with a stellar spectrum. The last diagram shows the detectability per spectral bin in units of sigma. See Tessenyi et al 2013 Methods.

b) SNR=10

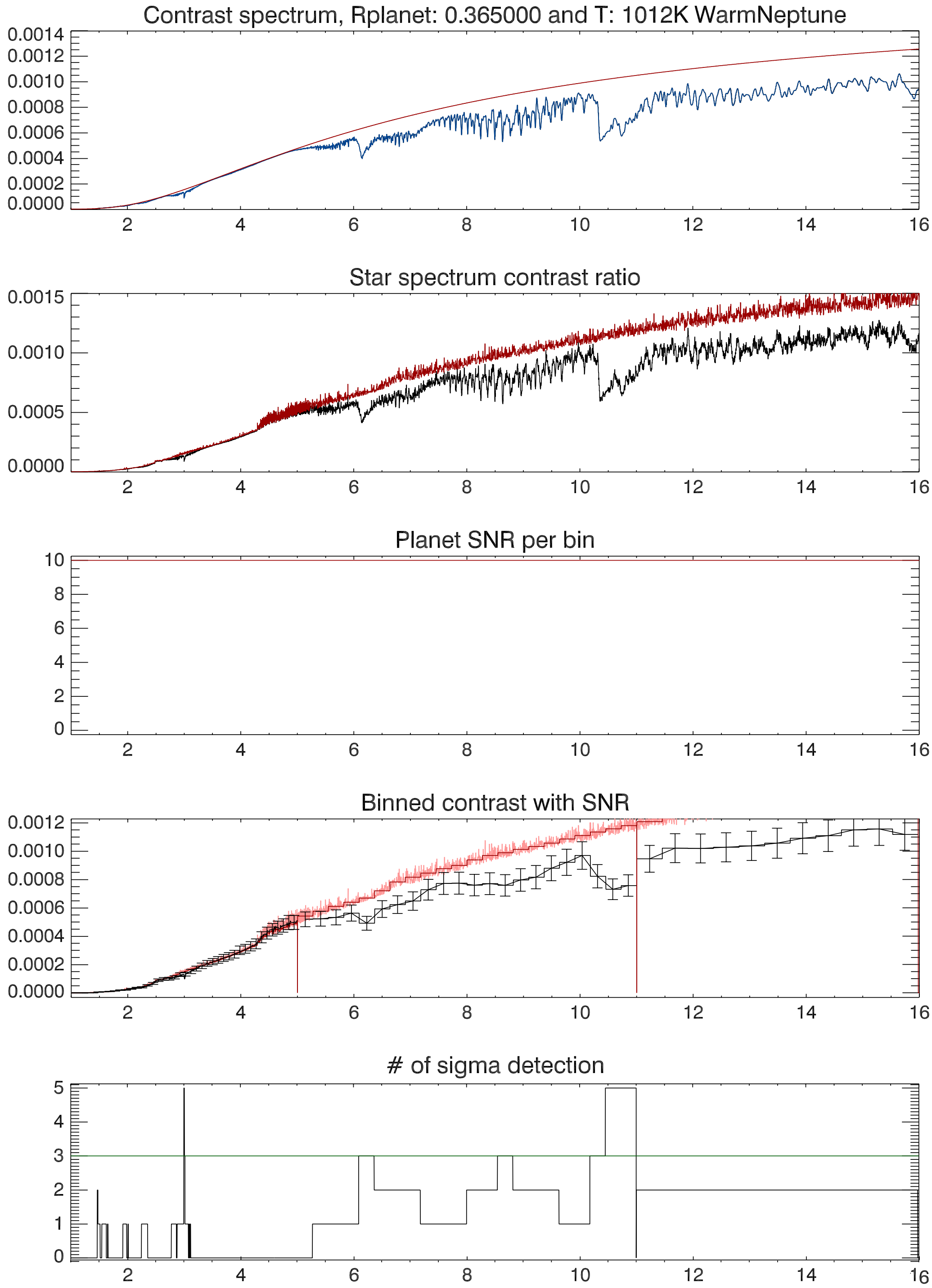

Figure 6: Fixed SNR bin-by-bin detectability method for a Warm Neptune, at SNR=10 and abundance 10^{-6}. The first diagram shows the planet/star contrast spectrum, where the star is a simulated blackbody. The second diagram is the same planet spectrum but with a stellar spectrum. The last diagram shows the detectability per spectral bin in units of sigma. See Tessenyi et al 2013 Methods.

c) SNR=20

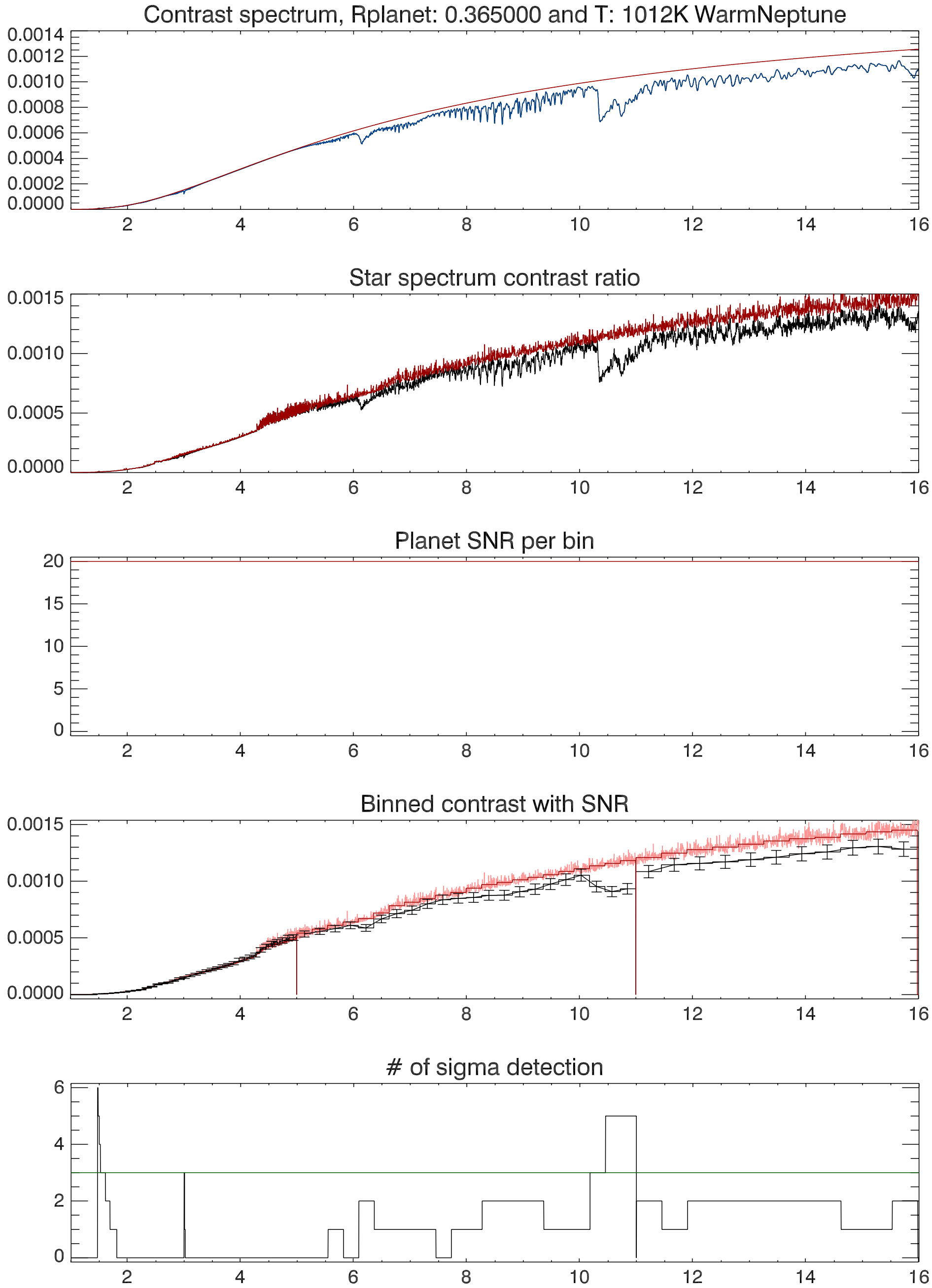

Figure 7: Fixed SNR bin-by-bin detectability method for a Warm Neptune, at SNR=20 and abundance 10^{-7}. The first diagram shows the planet/star contrast spectrum, where the star is a simulated blackbody. The second diagram is the same planet spectrum but with a stellar spectrum. The last diagram shows the detectability per spectral bin in units of sigma. See Tessenyi et al 2013 Methods.

Conclusions

The EChO required spectral coverage extending to 11µm is an optimal solution, nevertheless, if we discarded the information contained in the 10.6 to 11µm range, the NH_3 detectability would be unaffected.

Moses, J., Visscher, C., Fortney, J., et al. 2011, ApJ, 737, 15
Tessenyi et al., Icarus, ESL, in press. http://arxiv.org/abs/1308.4986
Venot, O., Hébrard, E., Agundez, M., et al. 2012, A&A, 546, A43
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