Detection of H_2O and evidence for TiO/VO in an ultra hot exoplanet atmosphere

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Introduction

WASP-121b is one of the hottest and most inflated gas giants currently known, with an equilibrium temperature of 2400K and radius of 1.8R_J (Delrez et al 2016, MNRAS, 458, 4025). Orbiting a J=9.6 mag host star, WASP-121b is one of the standout targets available for atmospheric characterisation, and may be hot enough for TiO and VO to be important gas phase absorbers. We observed a primary transit with HST WFC3 in spectroscopic mode on Feb 6 2016. Our primary goal was to determine if WASP-121b has a clear or cloudy atmosphere, by targeting absorption features due to H_2O, TiO, and VO across the 1.12-1.64μm wavelength range.

WFC3 G141 spectroscopic lightcurves

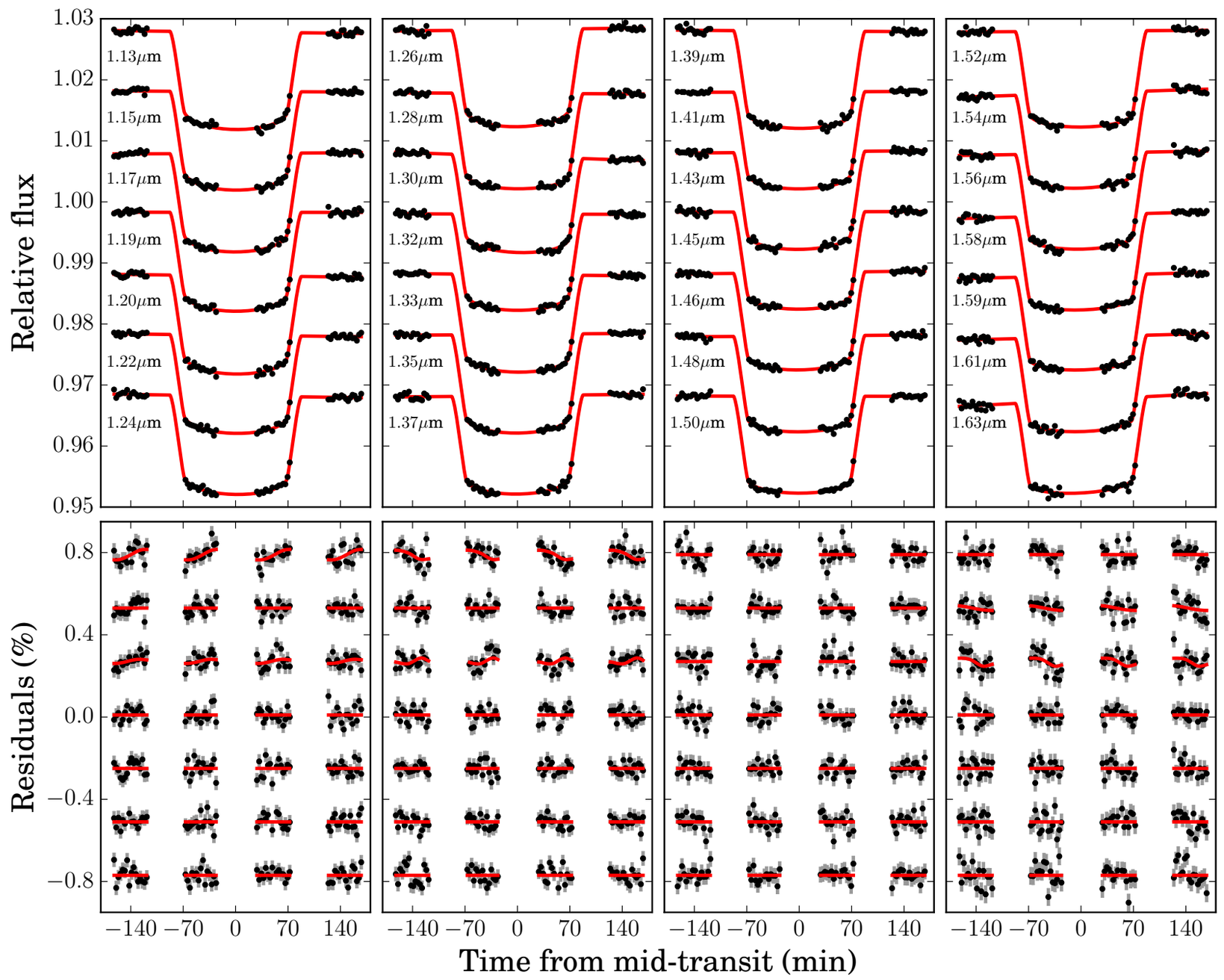

Figure 1. WFC3 spectroscopic lightcurves extracted for 28 channels across the G141 bandpass. The top panels show raw spectroscopic lightcurves with best-fit transit signals multiplied by linear time trends. The bottom panel shows model residuals with photon noise errorbars and Gaussian process (GP) model fits. Note that the transit signals, linear time trends, and GP systematics components were fit simultaneously as a single model in practice, but have been separated here for illustrative purposes.

WASP-121b transmission spectrum

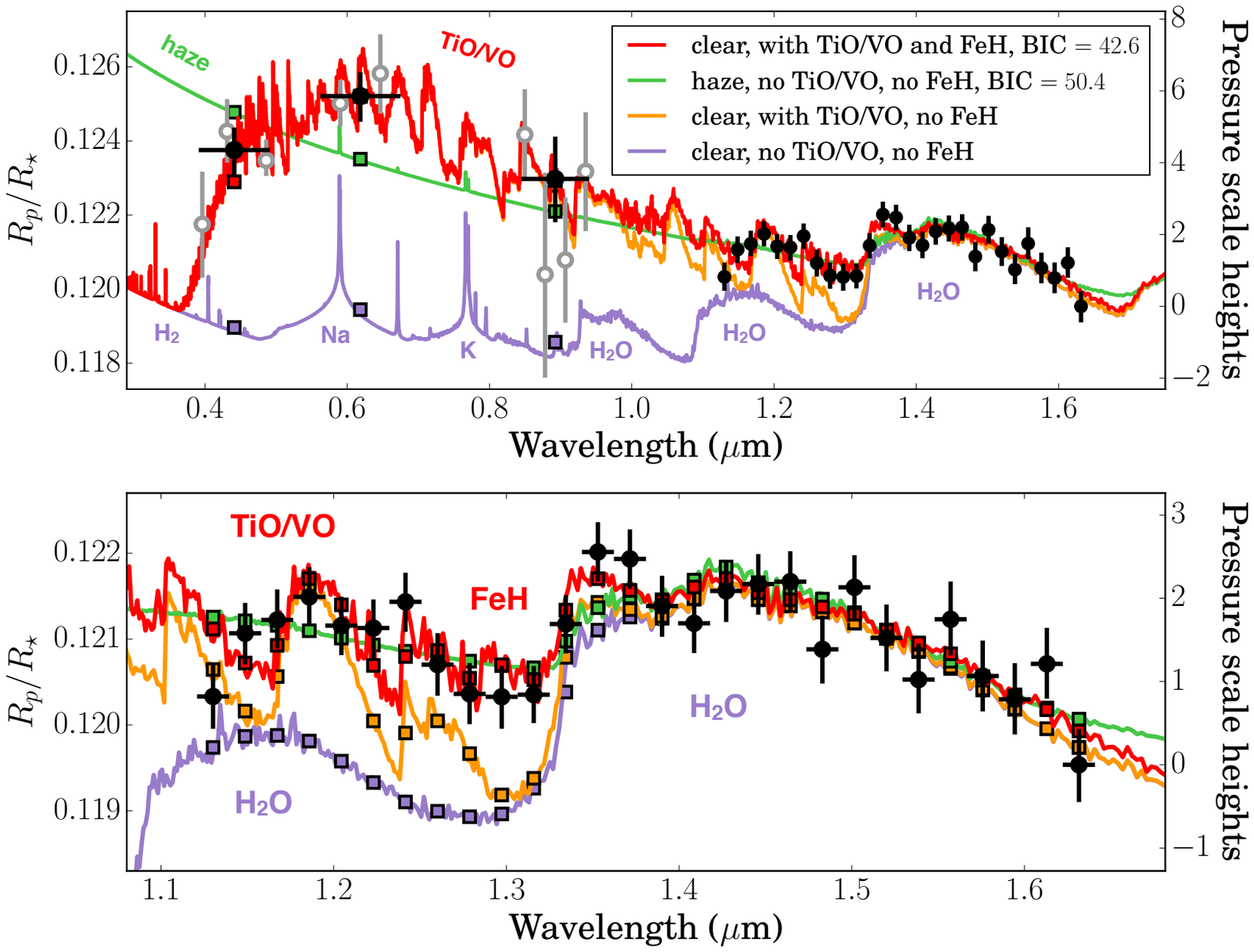

Figure 2. The resulting transmission spectrum for WASP-121b. In addition to the WFC3 data, we have also re-analysed ground-based optical lightcurves taken by the discovery team (Delrez et al) in the B, r′, and z′ bandpasses. These data are shown in the top panel. Unfilled grey points show analyses of individual photometric lightcurves and filled black points show joint fits for each bandpass. The bottom panel shows a zoom-in on the WFC3 data.

We obtain a good fit to the data with a model including TiO, VO, FeH, and H_2O absorption (red line). The H_2O detection is 5.4σ significance. The main evidence for TiO/VO comes from the larger effective radii measured at optical wavelengths relative to the near-infrared. A model including high-altitude haze but without TiO/VO provides a poorer fit (green line). When FeH is excluded, the model fails to reproduce the measured spectrum across the 1.12-1.33μm wavelength range (orange line). The approximate Bayes factor favours the best-fit TiO/VO model over the best-fit hazy model by exp[ΔBIC/2]=50:1, which roughly translates to 2.4σ confidence.

If confirmed, WASP-121b will be the first exoplanet with TiO, VO, and FeH detected in transmission. These are important species in M/L dwarfs and their presence is likely to have a significant effect on the overall physics and chemistry of the atmosphere, including the production of a strong thermal inversion.