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Is TiO responsible for a temperature inversion in hot Jupiter HD 179949b?

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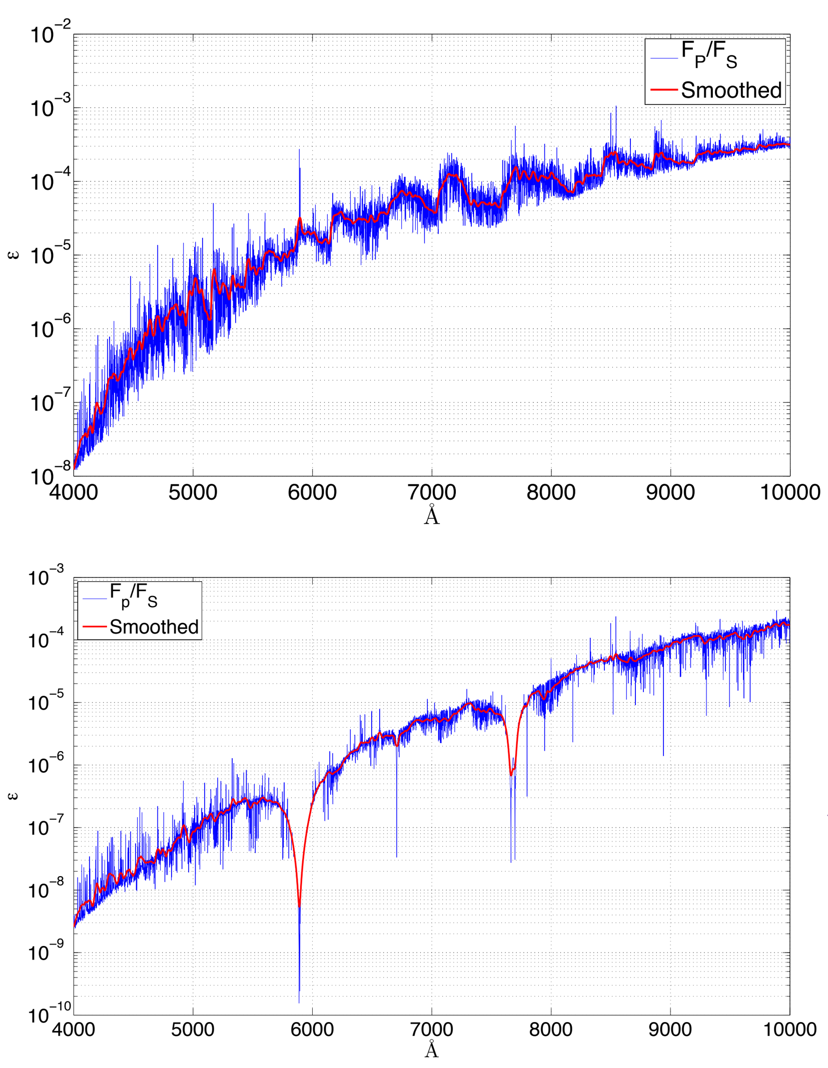
Abstract

We conduct a high resolution 0.6 - 0.9 µm spectral study of HD 179949b aimed at searching for the signatures of TiO and VO. These molecules may be responsible for the temperature inversion found in the most highly irradiated hot Jupiters. We obtained spectral time series of HD179949 with UVES over two nights, at phase angles when the planet is expected to be at its brightest. Using tomographic techniques, combined with signal enhancement via deconvolution, we probe planet/star contrast ratios of $F_p/F_\star = 10^{-4}$ - 10^{-5} at which the TiO/VO signatures are expected.

Two Proposed Atmospheric Models

The deconvolution process has been performed using two possible atmospheric models.

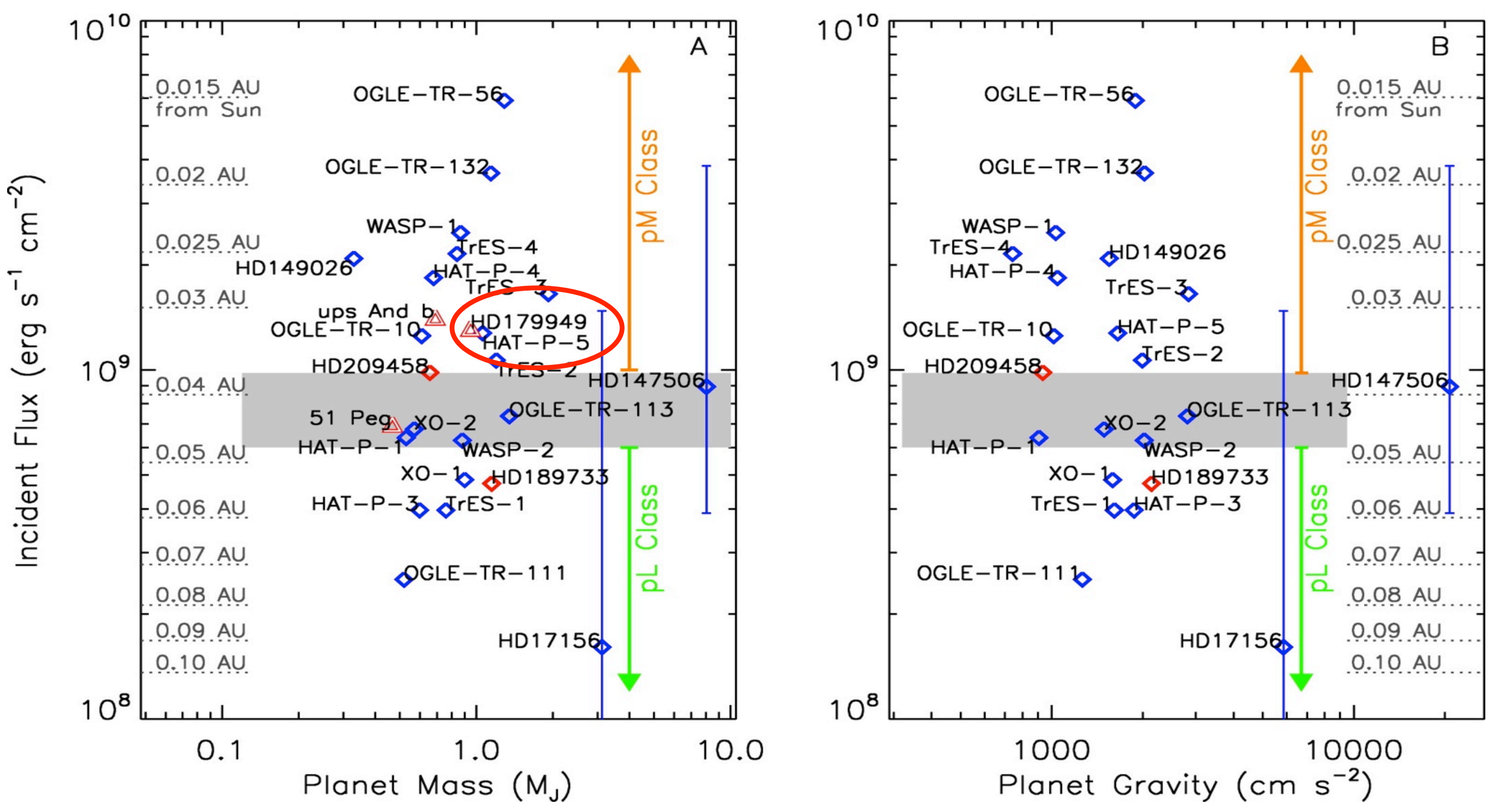


The hotter pM atmosphere is expected to be exhibit an emission line spectra and a high temperature difference between the day and night sides of the planet. This shows the expected contrast ratios between the host star and the emitted light from the planet as a function of wavelength.

The pL atmosphere is cooler and is expected to have absorption lines caused by H2O, Na, CO, and K and should have small day/night contrasts.

Expectations

HD179949b falls right in the transition region between a pM and pL atmosphere as predicted by Fortney et al with it being slightly more likely to expect a pM atmosphere.



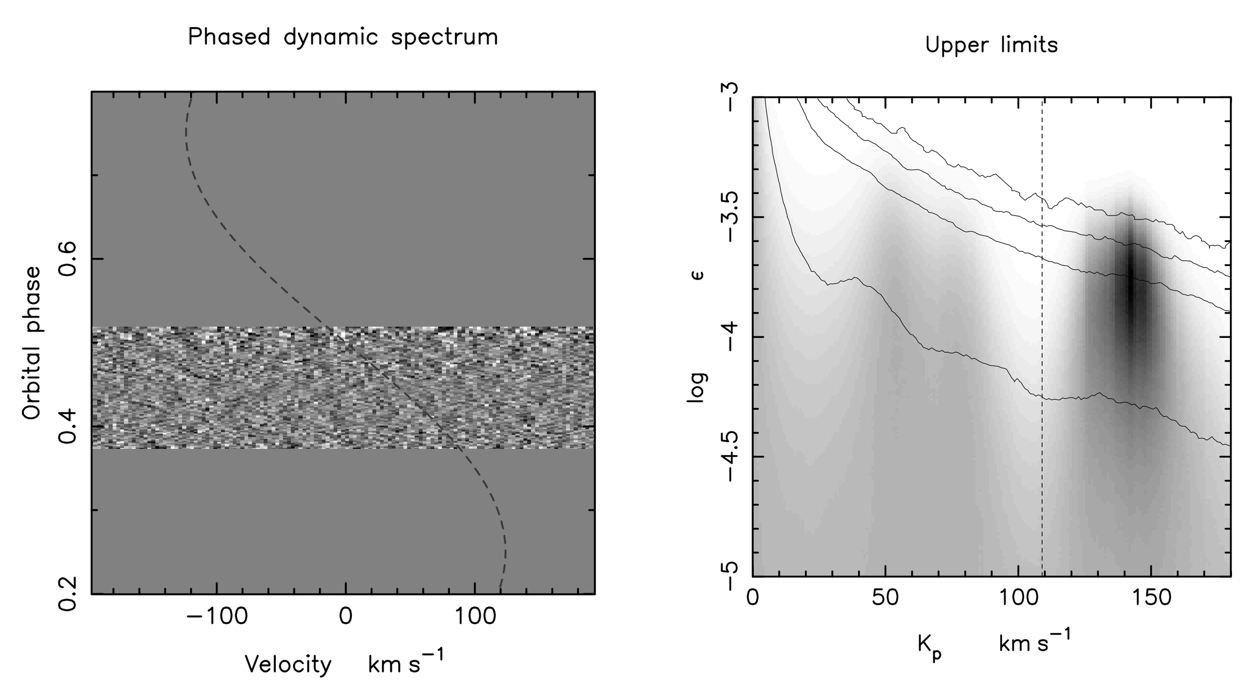
Observations

HD 179949 was observed continuously on the night of May 25th and 28th 2009 using the Ultraviolet and Visual Echelle Spectrograph (UVES) on the Very Large Telescope (VLT) at the La Silla observatory in Chile. These nights and times were specifically chosen so the planet would be as close to superior conjunction as possible so that the planet's illuminated area would be at a maximum.

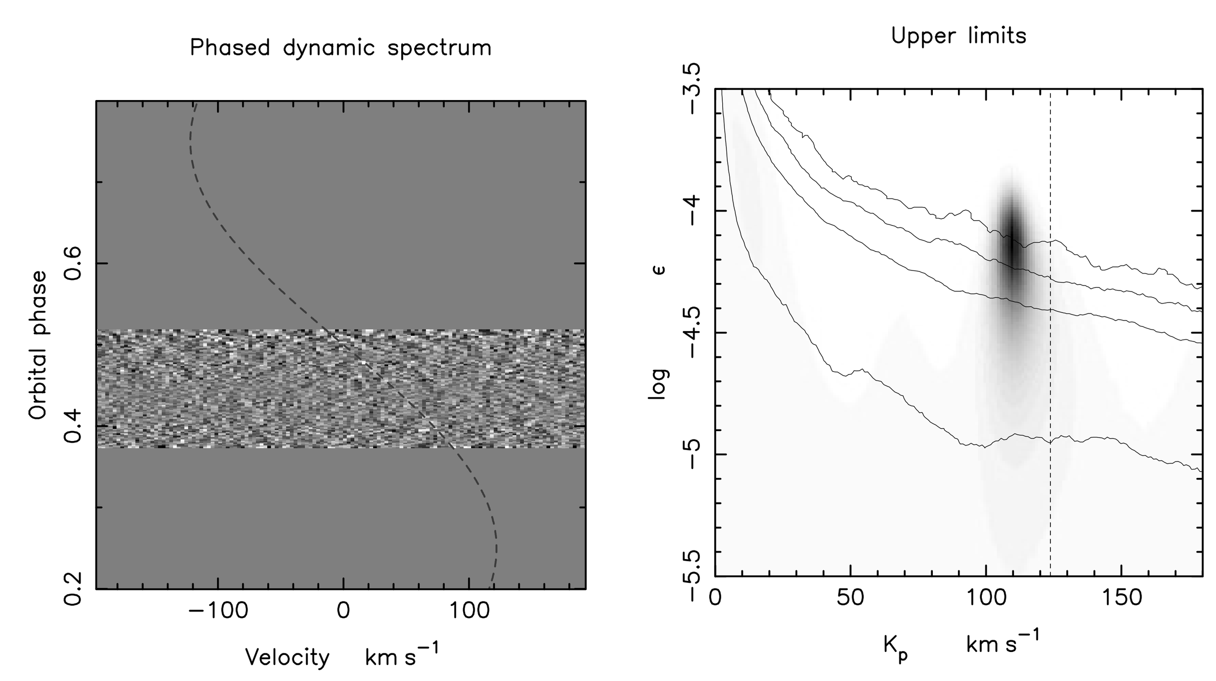
Analysis

The aligned spectra are summed together to produce a spectral template containing the stellar spectra, the tellurics, and a smeared planetary signal. Once the night template is scaled correctly, it is subtracted from the individual spectra producing a residual spectra containing noise and signal from the planet. The deconvolution process is then implemented using each of the atmospheric models. Below, the resulting residual time series for each atmosphere can then be seen.

Results



Above Left: The deconvolved time series from both nights of data with the most probably K_P plotted as a dashed line. For the pL atmosphere, we expect spectra along the dashed line to be in absorption. Above Right: a chi squared surface map of the best fit Epslion (F_p/F_S) and K_p using a pL atmosphere with this data set. The dotted line is the same as the left. The contour lines show confidence levels of a detection after a Bootstrap Monte Carlo simulation. From bottom to top, the lines are to show 68.4, 95.4, 99.0 and a 99.0 per cent confidence. For the pL atmosphere, the best solution is found at a $\log_{10}$ Epsilon = -3.79 at a confidence level of about 95 per cent. This is inconsistent with expected results by by 3 orders of magnitude so deemed likely to be caused by a spurious signal.



Same as above but using the pM atmosphere. Here, a signal can be seen at the relatively high confidence of 99.9 per cent and the $\log_{10}$ Epsilon = -4.14 which is consistent with expectations. However, further on-going investigation has hinted that this detection may be caused by systematics within the data set. We can say with confidence, though, that there is no strong detection of the planet using this atmosphere at down to a $\log_{10}$ Epsilon = -4.0

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