A FORS2 Transmission Spectrum for the Hot Saturn WASP-49b

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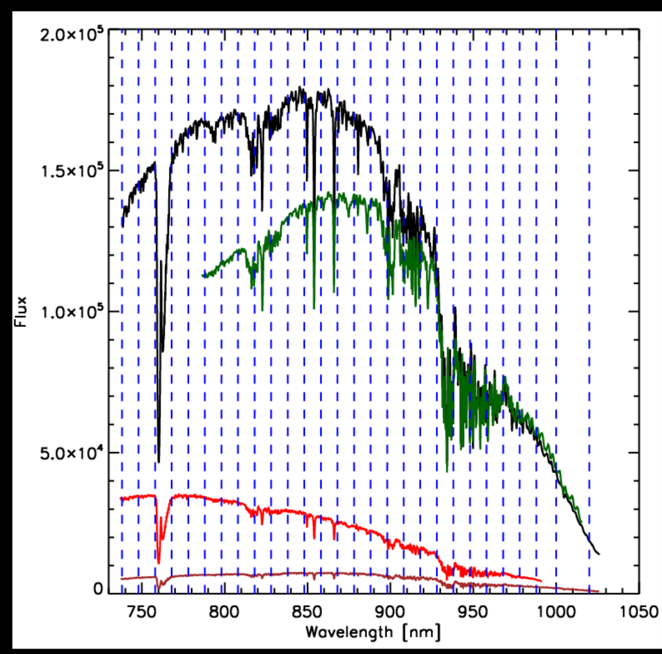
Method & Target

Multi-wavelength observations of exoplanet transits are one of the currently accessible means for studying the atmospheric properties of exoplanets. Wavelength-dependent variations in the transit depth reveal the planetary transmission spectrum and allow to constrain the atmospheric composition and evaluate the presence of clouds or hazes.

We use spectro-photometric observations to apply this technique on the hot Saturn WASP-49b. WASP-49b (Lendl et al. 2012), is a low-density (rho_p = 0.27 rho_J) M_p = 0.38 M_J, R_p = 1.12 R_J planet orbiting a G6 star every 2.792 days. It is predicted to show large signatures in transmission due to its low density and high temperature.

Observations & Reduction

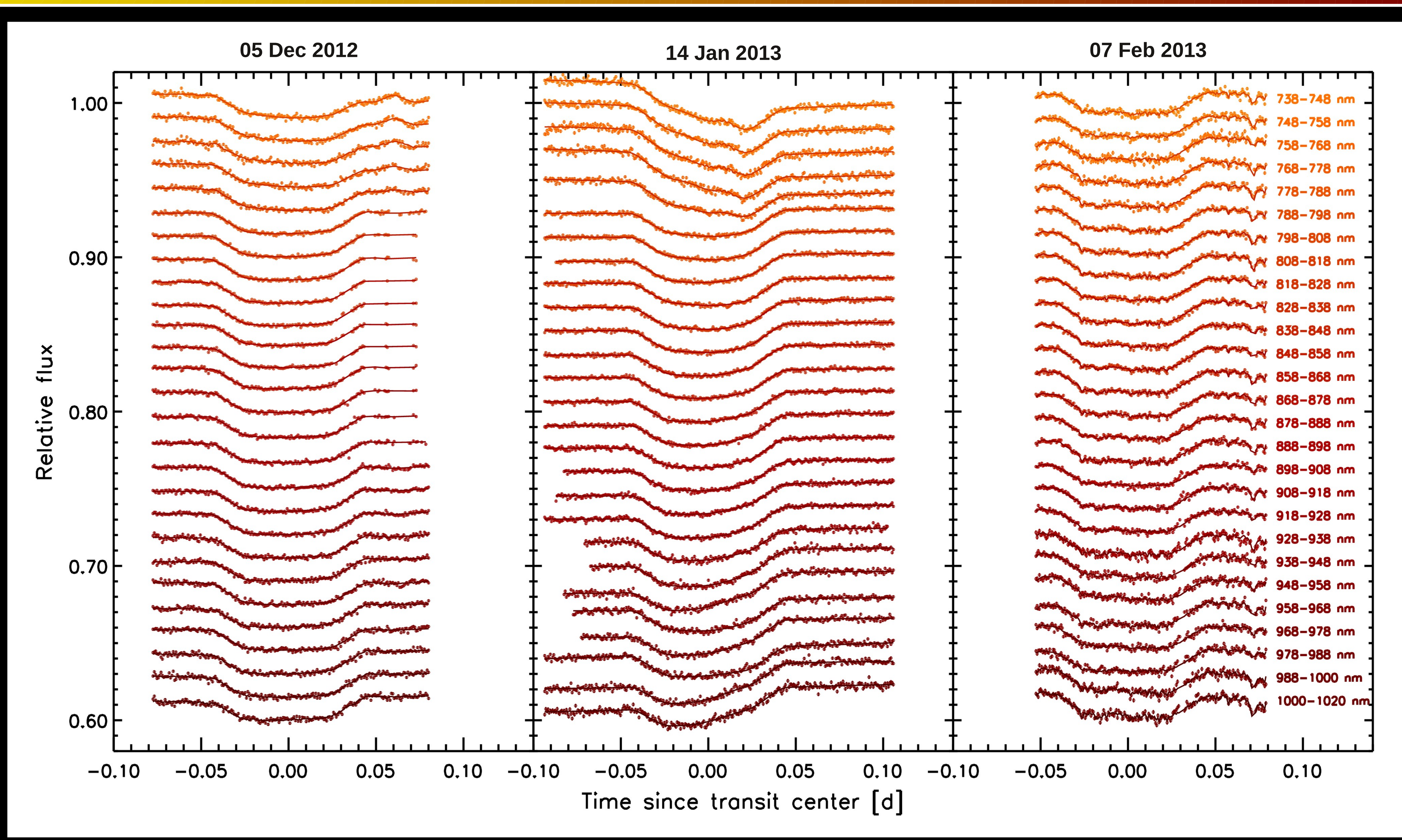
We used the FORS2 instrument (Appenzeller et al. 1999) at the ESO VLT/UT1 telescope to observe three transits of WASP-49b in multi-object spectroscopy mode. Large slits (10") were used to select the target and three reference stars. During the observations, the Linear Atmospheric Dispersion Corrector (LADC) separation angle was kept constant to reduce correlated noise created by inhomogenities in the LADC transmission (see Mohler et al. 2010 for details). The light was dispersed using the GRIZ600z grating to produce spectra ranging from 730 to 1020 nm. After extracting the spectra, we binned the each spectrum in 10 nm wide bins and produced transit lightcurves (shown below) via relative photometry.



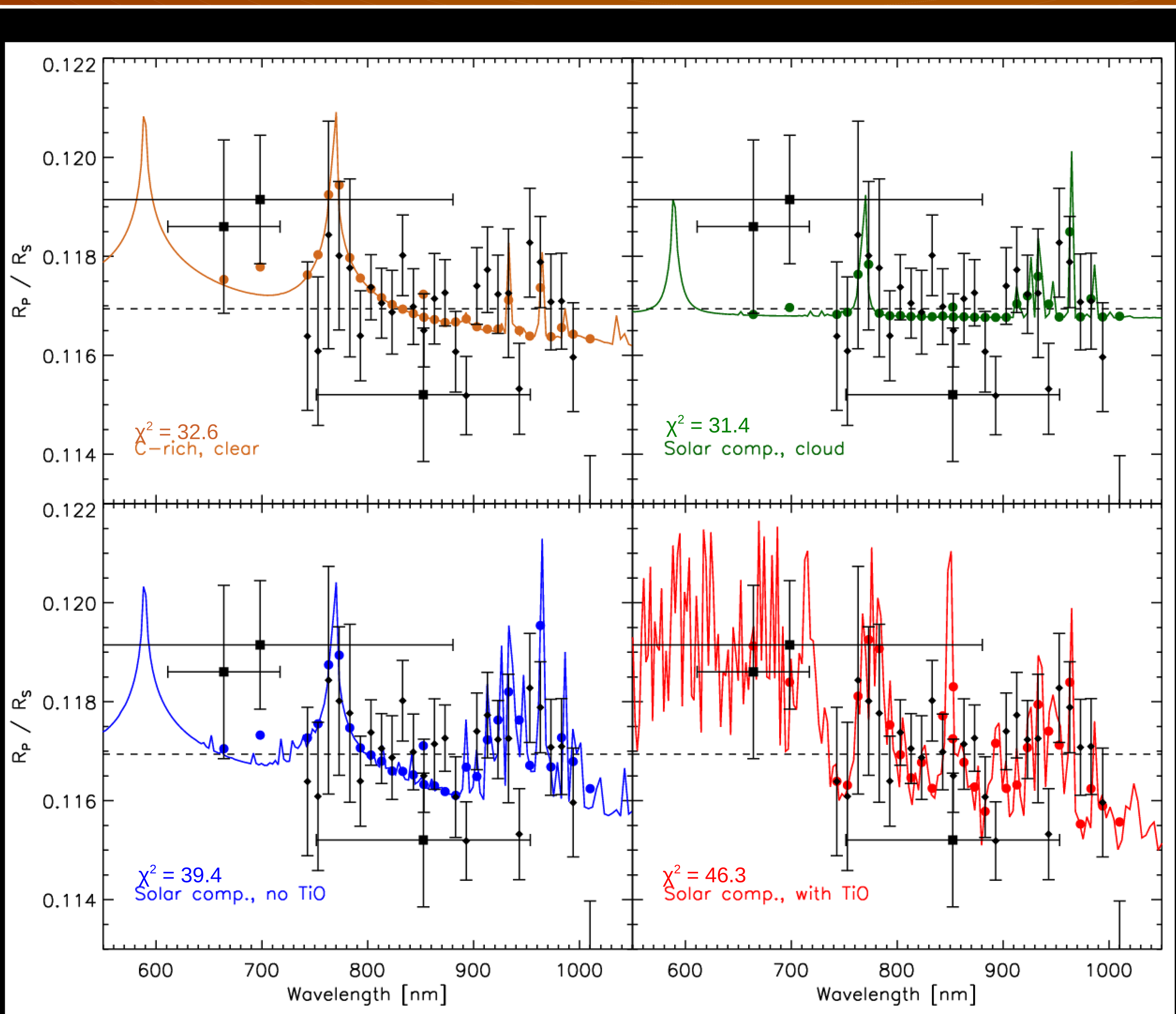
Target (black) and reference star spectra. The spectral bins are idicated in blue.

Key Points

- We obtained three transits with FORS2 to infer the transmission spectrum of WASP-49.
- Correlated noise due to the LADC can be modeled using functions of the parallactic angle.
- The resulting spectrum is fit best by atmospheric models with small features: An atmosphere possessing a cloud deck, or a large Carbon abundance. A straight line also gives a good fit to the data.



The FORS2 lightcurves of three transits of WASP-49b. The dates are (from left to right) 05 Dec 2012, 14 Jan 2013, and 07 Feb 2013. The trends and short term photometric variations visible in some lightcurves stem from LADC inhomogenities. Some data of 05 Dec 2012 were affected by saturation.



The transmission spectrum of WASP-49b. All three FORS2 observations were analyzed simultaneously together with a number of broad-band observations from other facilities. The best fit to the data is given by the Solar composition model with a cloud deck (green, top right). A straight horizontal line gives χ^2 = 33.0 .

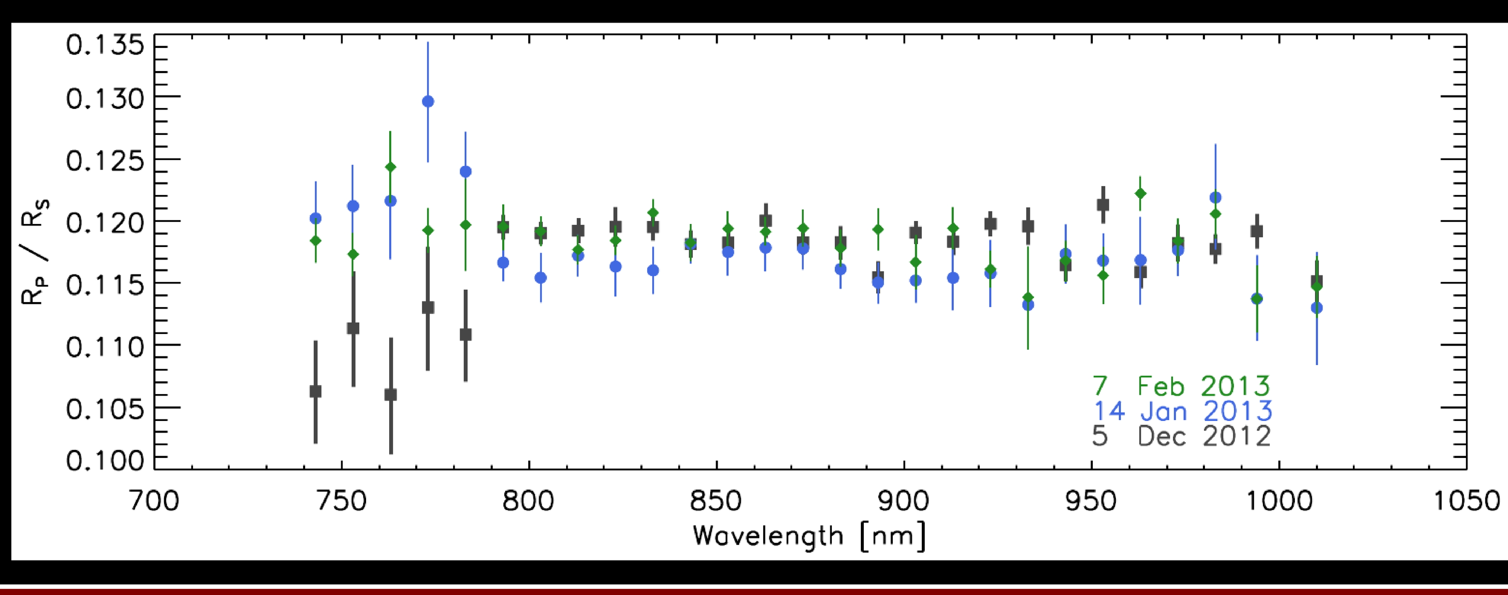
Analysis

Contamination: a Δmag_z=4.3 fainter component was discovered at 2.3 arcsec from WASP-49 during pre-imaging. We estimated the contamination from the FORS2 spectra and corrected the lightcurves accordingly.

Transit Modeling: we used an MCMC approach to perform a global analysis of the FORS2 data together with a number of wide-band lightcurves observed with EulerCam (Lendl et al. 2012) and TRAPPIST (Jehin et al. 2011). The MCMC code used is described in detail by Gillon et al. (2012). One of the major issues was to account for correlated noise due to inhomogeneous transmission of the LADC . We were able to model these components using photometric baseline models including the parallactic angle. The respective parameters were derived together with the transit parameters.

Model Atmospheres: The model atmospheres were generated using the procedure described by Madhusudhan & Seager (2009) and Madhusudhan (2012). We tested several compositions, with varying C/O abundances and with/without the presence of TiO, as well as a cloud deck at a pressure level of 10 mbar.

Individual observations: We also extracted transmission spectra for each FORS2 observation, to check the reliability of the obtained transmission spectrum. The observations are in good agreement with each other (see Figure below), but show a slight offset.



The FORS2 data of each transit observation analyzed individually. The bluest five bins show large error bars due to high correlated noise and thus complex photometric baseline models.

References

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