Towards a Transmission Spectrum of the Hot Saturn WASP-49b

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Abstract

Transiting extrasolar planets are so far the only planets whose atmospheres can be studied in detail. The spectro-photometric observation of transits allows to search for wavelength dependencies in the effective planetary radius that are sensitive to signatures of chemical elements in the planetary atmosphere.

We present first results from an observing campaign carried out using the FORS2 instrument to obtain spectro-photometric observations of transits of the low-density hot Saturn WASP-49b.

Observations

We observed three transits of WASP-49b using FORS2 (Appenzeller et al. 1998) located at the VLT/UT1 in multi-object spectroscopy (MXU) mode. We obtained R~1400 resolution spectra of WASP-49 as well as three reference stars covering a wavelength range of 740 – 1030 nm for the target. The wavelength coverage of the reference stars is slightly reduced due to positioning limitations. Conditions were excellent during the first observation, while seeing was variable (1" – 2") during the second observation and clearly below average (seeing 1.5" – 2.5") for the third transit. We used wide (10") slits to avoid flux losses at the slit edges.

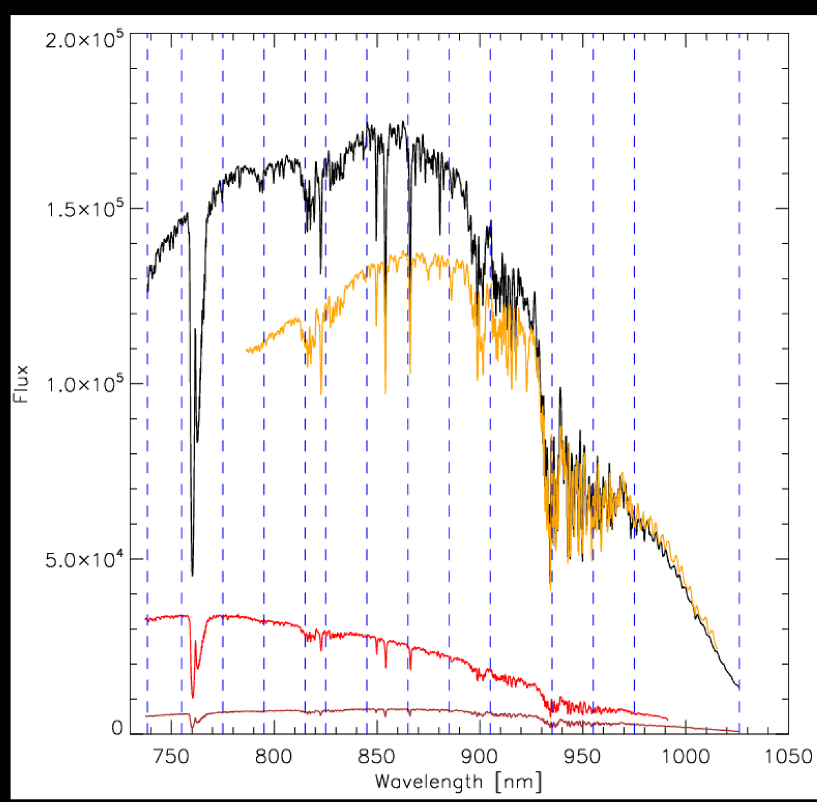
One of the major limitations in precision has been shown to be caused by inhomogeneities in the transmission of the linear atmospheric dispersion corrector (LADC), which is composed of two large prisms. Moehler et al. (2010) offer a detailed description of the effect. To reduce effects on the lightcurves, we put the LADC in simulation mode. However, the separation of the two prisms varied between the three dates: nearly closed for the first, open for the second and closed for the third.

WASP-49b

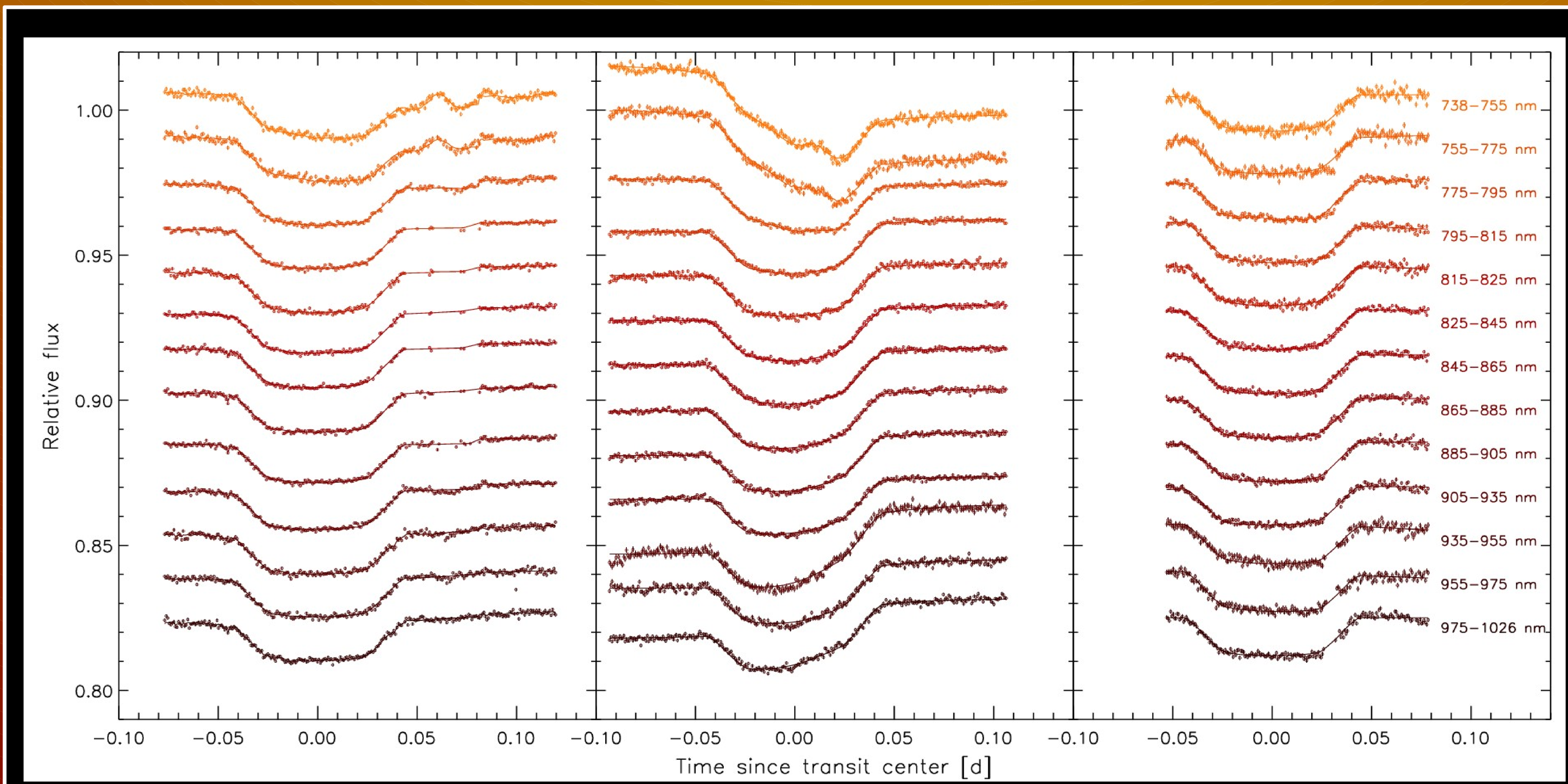
WASP-49b (Lendl et al. 2012) is a $M_p = 0.38\ M_J$, $R_p = 1.12\ R_J$ planet recently discovered by the SuperWASP survey (Pollacco et al. 2006). This hot (T_{eq} = 1369 K) bloated ($rho_p = 0.27\ rho_J$) planet is orbiting a relatively bright (V = 11.36 mag) G6 star every 2.792 days. Given its high atmospheric scale height (H_p/R_p=0.009), deep (1.4 %) and frequent transits, and good nearby reference stars it makes an ideal target for transmission spectroscopy.

Data Reduction

We use standard pipeline products for the basic image corrections i.e. bias and flat field corrections as well as to obtain a first wavelength calibration of the spectra. Further refinement on the wavelength solution is made by matching prominent lines in the extracted spectra of all stars. This way, we compensate small residual shifts of about 3 Å. The spectra are extracted from the images by means of IDL routines written for this purpose. In short, at each pixel in the dispersion direction, the center of the line is determined and the flux is summed along the spatial axis within a chosen aperture. Cosmics are rejected at this stage and replaced by interpolated values. A second pass on cosmic rejection uses the time dimension of the extracted spectral information. Lightcurves are created for each spectral element, and outliers are rejected. Finally, the spectra are binned to produce the lightcurves depicted.



Mean spectra of WASP-49 (black) and three reference stars. The blue vertical lines denote the bins used for spectro-photometry

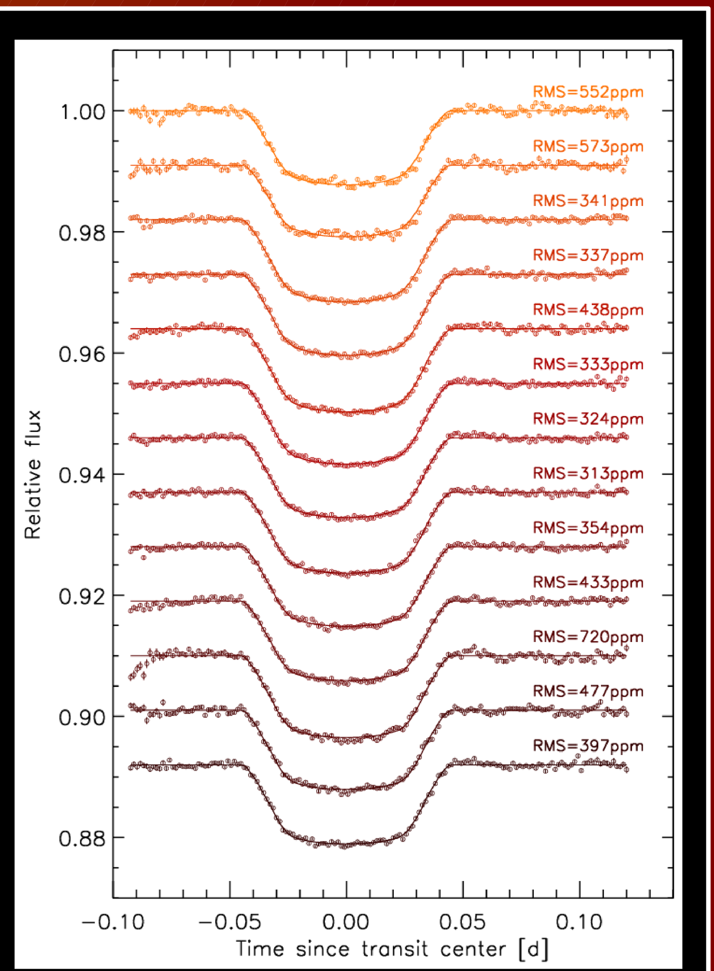


Data obtained on 2012-12-05, 2013-01-14 and 2013-02-07, respectively. The best-fit baseline and transit models are overplotted.

Modeling

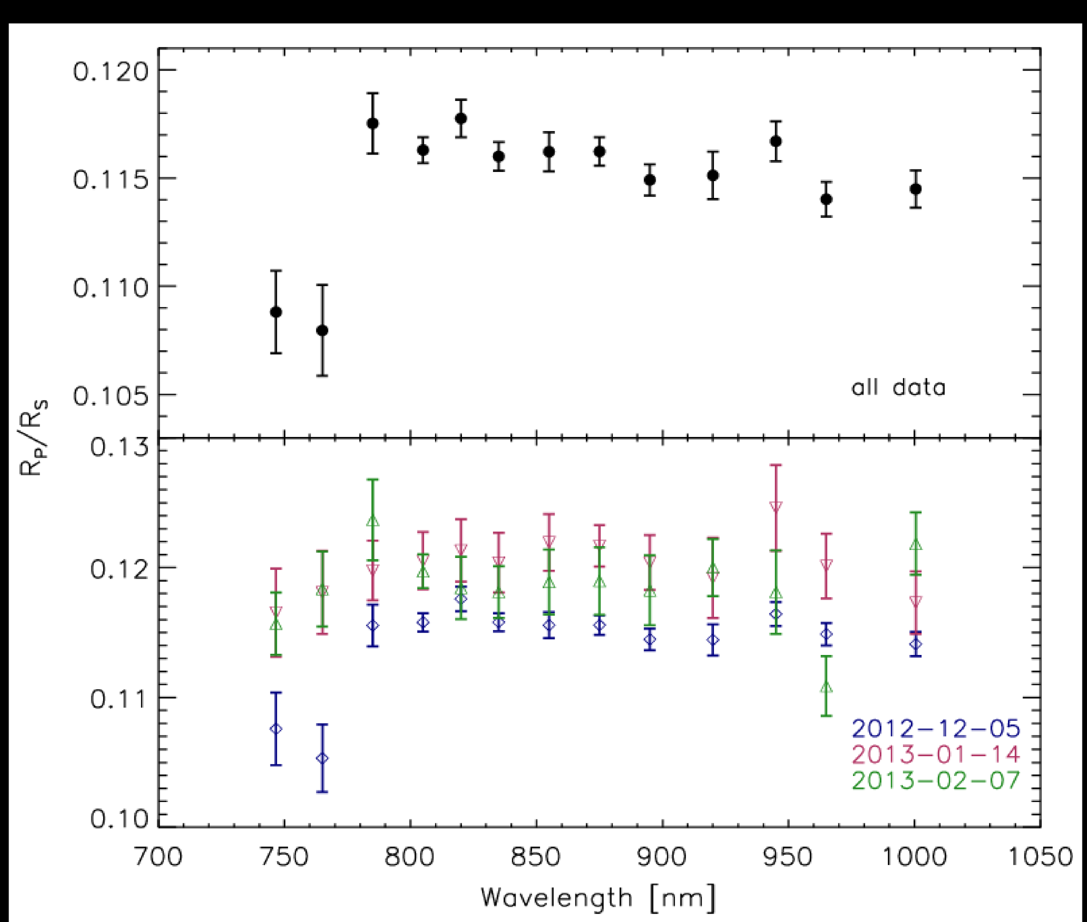
Each light curve was modeled using the MCMC code described in Gillon et al. 2012. We test different models for the photometric baseline, that include parameters such as the spectral FWHM and the sky background. A more complicated model is chosen over a simpler model only if the Bayes factor indicates a significantly higher probability. Most lightcurves were modeled with only a minimal model including dependences on the parallactic angle, in some cases additional terms in time, FWHM, and sky were beneficial.

All error bars are scaled up in order to account for underestimated white and red noise.



All lightcurves corrected for the respective baseline models, phase-folded and binned in bins of 2 minutes.

Preliminary Results



All wavelength channels have been modeled simultaneously, allowing only the transit depth to vary between lightcurves. We present the inferred star/planet radius ratios for a simultaneous analysis of all three dates (upper panel) as well as a separate treatment of each date (lower panel).

The first lightcurve is yielding the most precise results, owing to the clearly superior data quality. Yet the first two wavelength bins show significantly lower planetary radii than the others. This is not reproduced for the other dates, and needs to be carefully verified.

A more detailed analysis and interpretation of the data is ongoing.

LADC effect

Since the position of the LADC is related to the parallactic angle, we include the parallactic angle as a baseline parameter for all lightcurves. This way we can fit the overall distortion of the lightcurves which is most extreme for the data obtained during the second transit. The lightcurves obtained at short wavelengths show a high-frequency pattern at meridian passage, probably related to chromatic effects in the LADC transparency. These variations can be removed by means of a 4th order polynomial in the change of parallactic angle.

References

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