AIP
Leibniz-Institut für Astrophysik Potsdam

VATICAN OBSERVATORY

LARGE BINOCULAR TELESCOPE

PEPSI
The Potsdam Echelle Polarimetric and Spectroscopic Instrument

Exoplanet spectroscopy with LBC, MODS and PEPSI

Silicate aerosols in the atmosphere of the hot Jupiter HAT-P-32b

M. Mallonn, E. Keles, K. G. Strassmeier (AIP)

Transmission spectroscopy of hot Jupiter exoplanets

We use the three optical instruments LBC, MODS & PEPSI at the Large Binocular Telescope (LBT) to measure the transmission spectra of extrasolar planets. Independent LBC and MODS transit measurements of the hot Jupiter HAT-P-32b provide evidence for a scattering signature of aerosols in the planetary spectrum. Potential condensate species of these aerosols are silicates like forsterite or enstatite. PEPSI will be able to resolve the spectral absorption above the haze or cloud layer of, e.g., sodium in much higher spectral resolution. Our group did first transit observation for the hot Jupiter XO-2b.

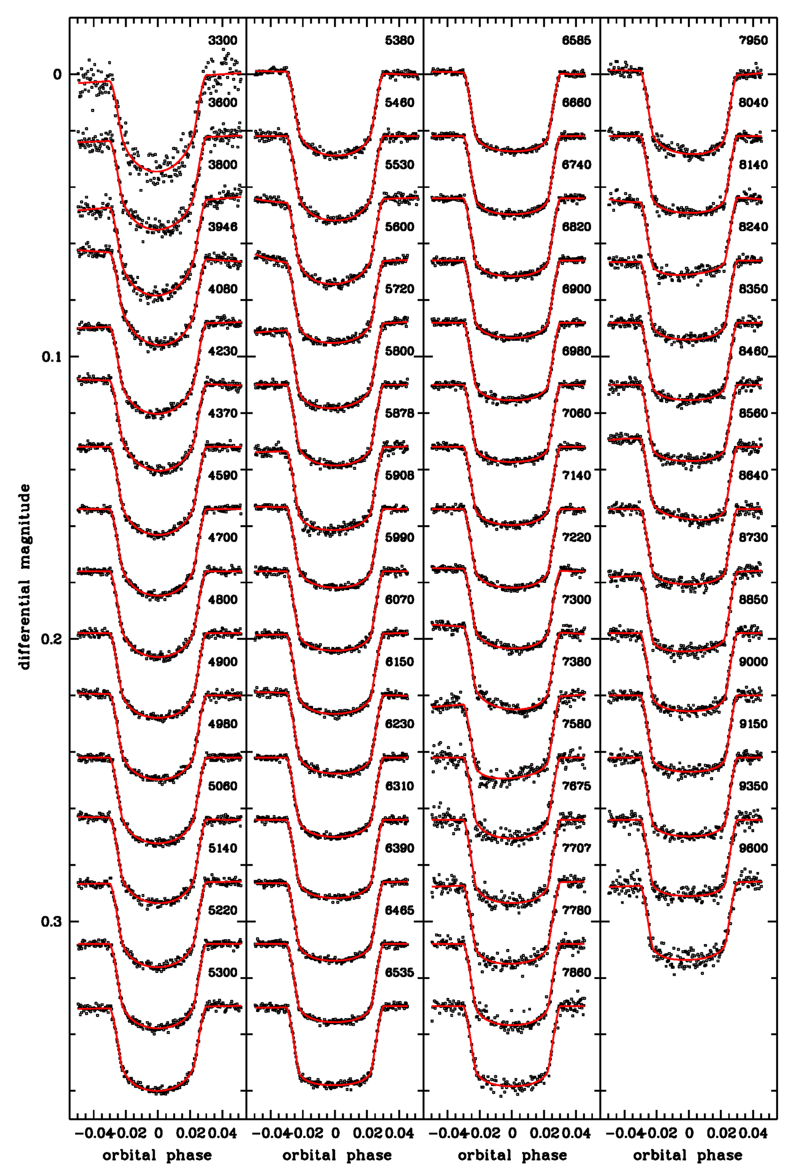

Fig. 1: Set of spectrophotometric transit light curves of HAT-P-32b observed simultaneously with MODS.

A planetary spectrum with MODS

The time-series spectra of MODS covering a transit event of HAT-P-32b were binned in wavelength channels of ~100 Å width to create a set of spectro-photometric light curves (Fig. 1). From a modeling of these light curves we derived a planetary transmission spectrum of spectral resolution R~60 (Fig. 2) that ruled out a cloud/haze-free solar-composition atmosphere model (green). Instead, a model dominated by a scattering slope is preferred (Mallonn & Strassmeier 2016). MODS proved its capabilities to characterize an exoplanet atmosphere by high-precision spectrophotometry with only a single transit event of 5 hours duration.

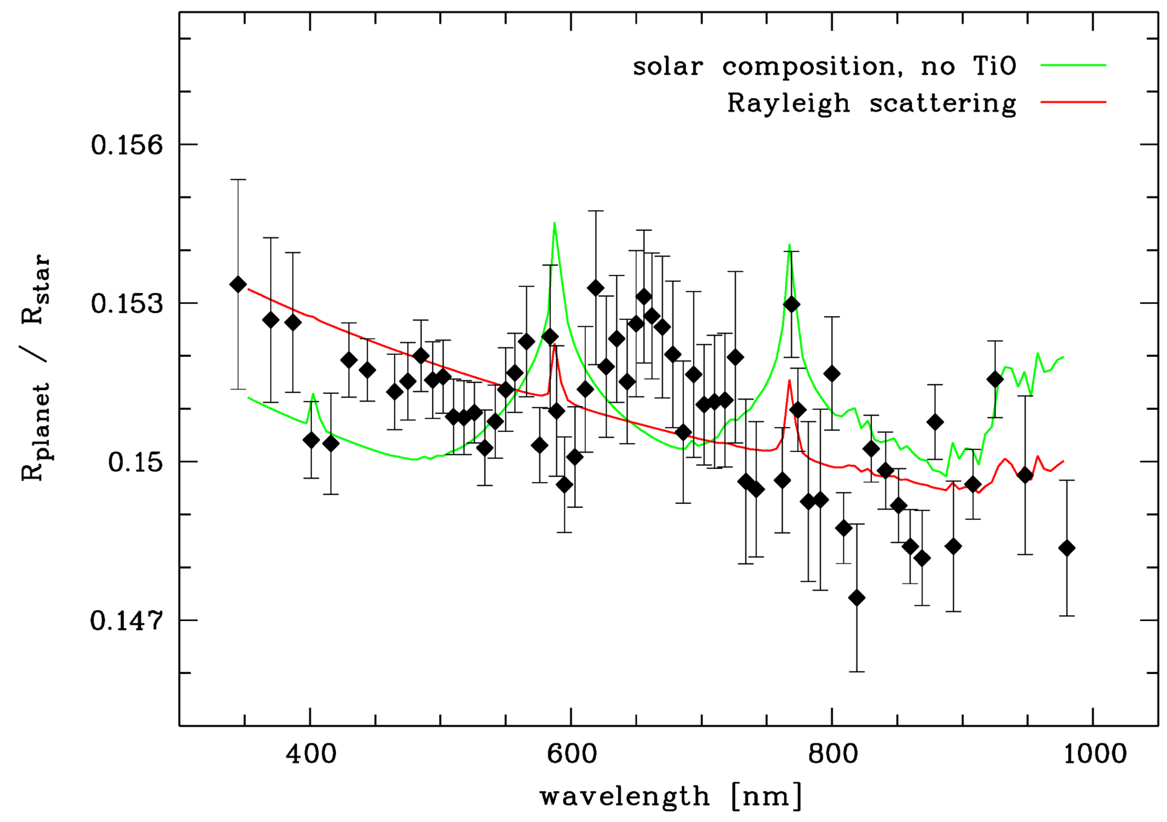

Fig. 2: Transmission spectrum of HAT-P-32b observed with MODS from 350 to 1000 nm. The solar-composition atmosphere model (green) is ruled out.

Best ground-based near-UV light curve with LBC

We obtained broad-band photometry of many transit events of HAT-P-32b in nine different filters to derive a very-low resolution transmission spectrum of the planet. The scattering signature is most pronounced at short optical wavelength, where the host star is intrinsically fainter. Thus, we made use of the LBT with the LBC to observe a transit light curve of sub-mmag precision (Fig. 3). The broad-band transmission spectrum confirms the scattering slope already found in the MODS spectrum and the lack of absorption by atomic sodium (Fig. 4, Mallonn 2017). According to the equilibrium temperature, the scattering aerosols could be formed by condensation of silicates like forsterite or enstatite (Wakeford et al. 2017). The optical slope is related to the particle size. We compared the slope of HAT-P-32b to literature values of other investigated exoplanets, finding the optical spectrum of HAT-P-32b to be average (Fig. 5). No correlation was found of the amplitude of the optical slope to the planet equilibrium temperature nor to its surface gravity or the stellar activity (Mallonn 2017).

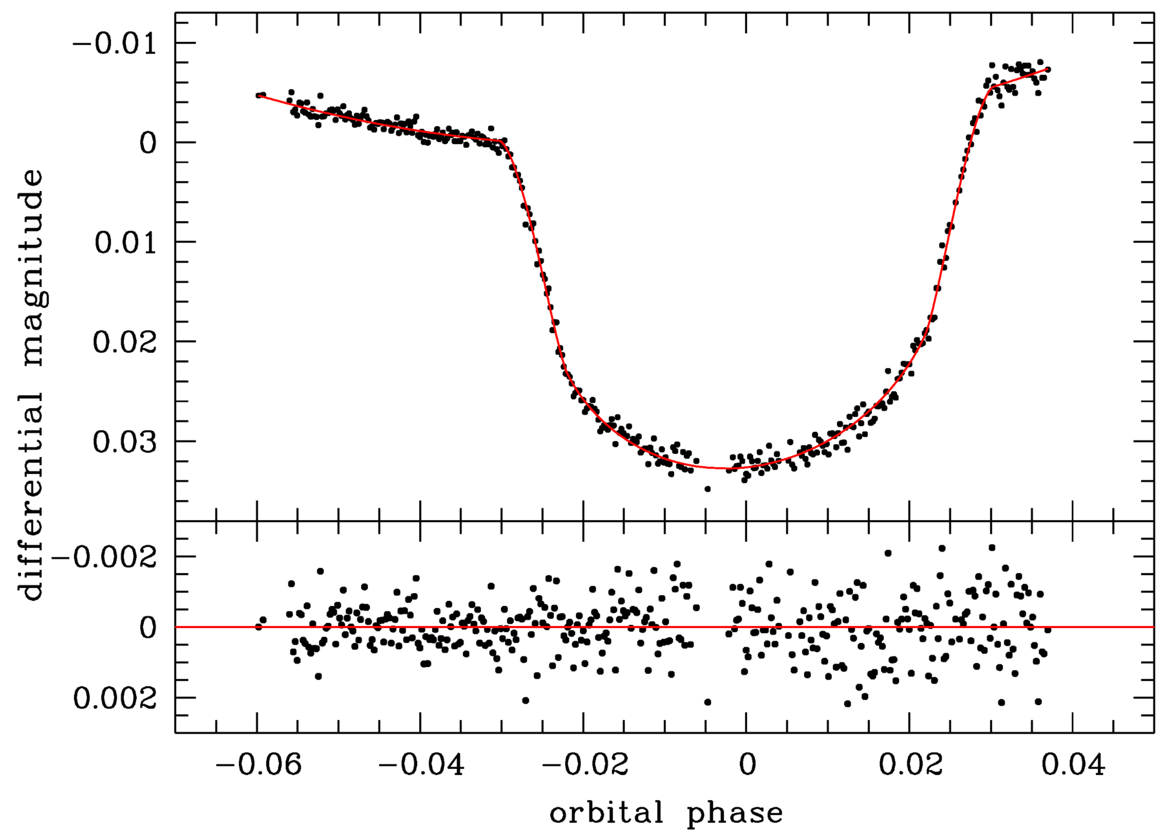

Fig. 3: Transit light curve of HAT-P-32b observed with the LBC. This data set forms the highest-quality ground-based near-UV light curve obtained so far. The red line is a transit model including detrending, the lower panel shows the light curve residuals of rms 0.7 mmag.

References:
Mallonn & Strassmeier 2016, A&A, 590, 100
Mallonn 2017, AN, submitted
Wakeford et al. 2017, MNRAS, 464, 4247

Transmission spectroscopy with PEPSI

We observed a transit event of another gas giant XO-2b in high spectral resolution (R=120k) with PEPSI to target sodium absorption by the planetary atmosphere. The strength of this spectral feature can be revealed as differential measurement in-transit versus out-of-transit. The analysis is work in progress. In Fig. 6, a spectrum of the time-series is presented showing the sodium D lines of the host star. In the near future, we want to combine low-resolution exoplanet transmission spectra from MODS with high-resolution transmission spectra observed with PEPSI to constrain the sodium abundance of the exoplanet atmosphere and the pressure level of the cloud/haze layer often found in hot Jupiter atmosphere.

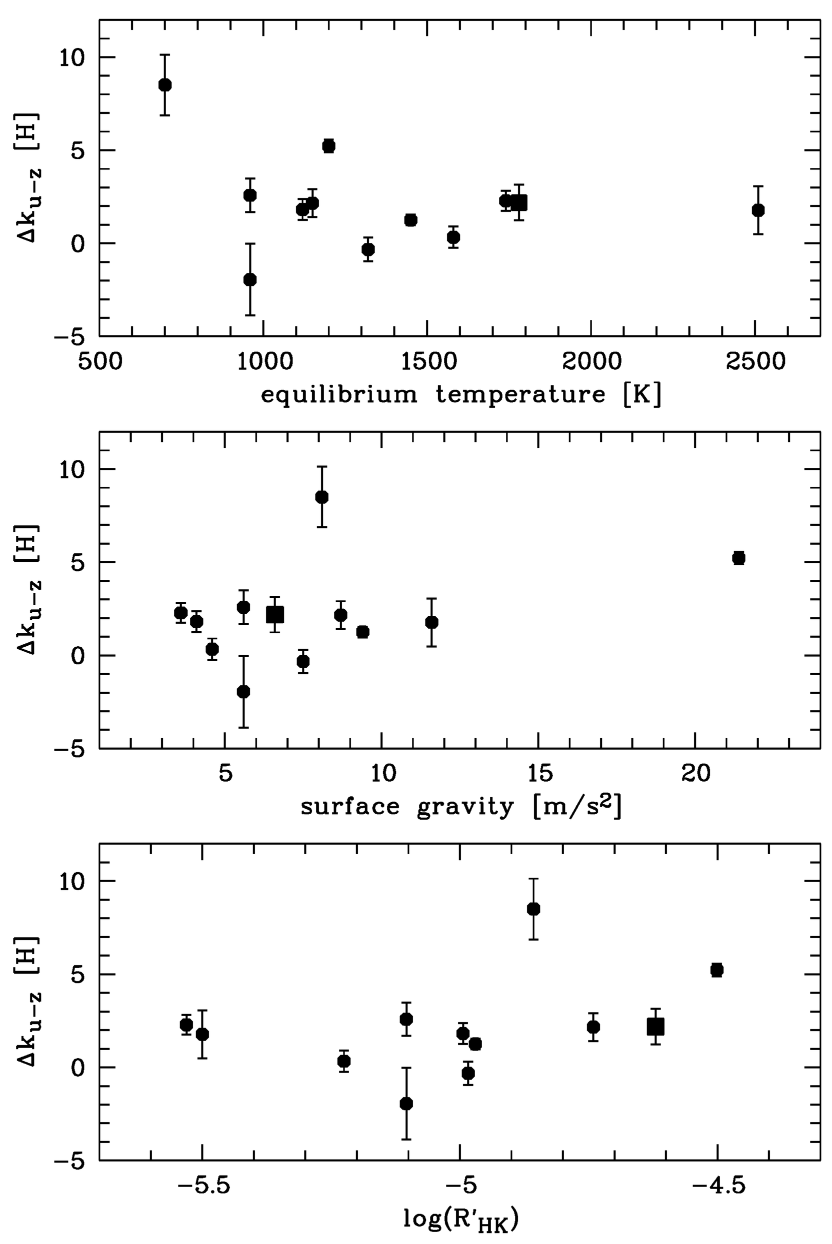

Fig. 5: The optical spectral slope of extrasolar planets in relation to planetary and stellar parameter. HAT-P-32b from our work is the quadratic data point. No correlation between the measured spectral slope and the parameters was found.

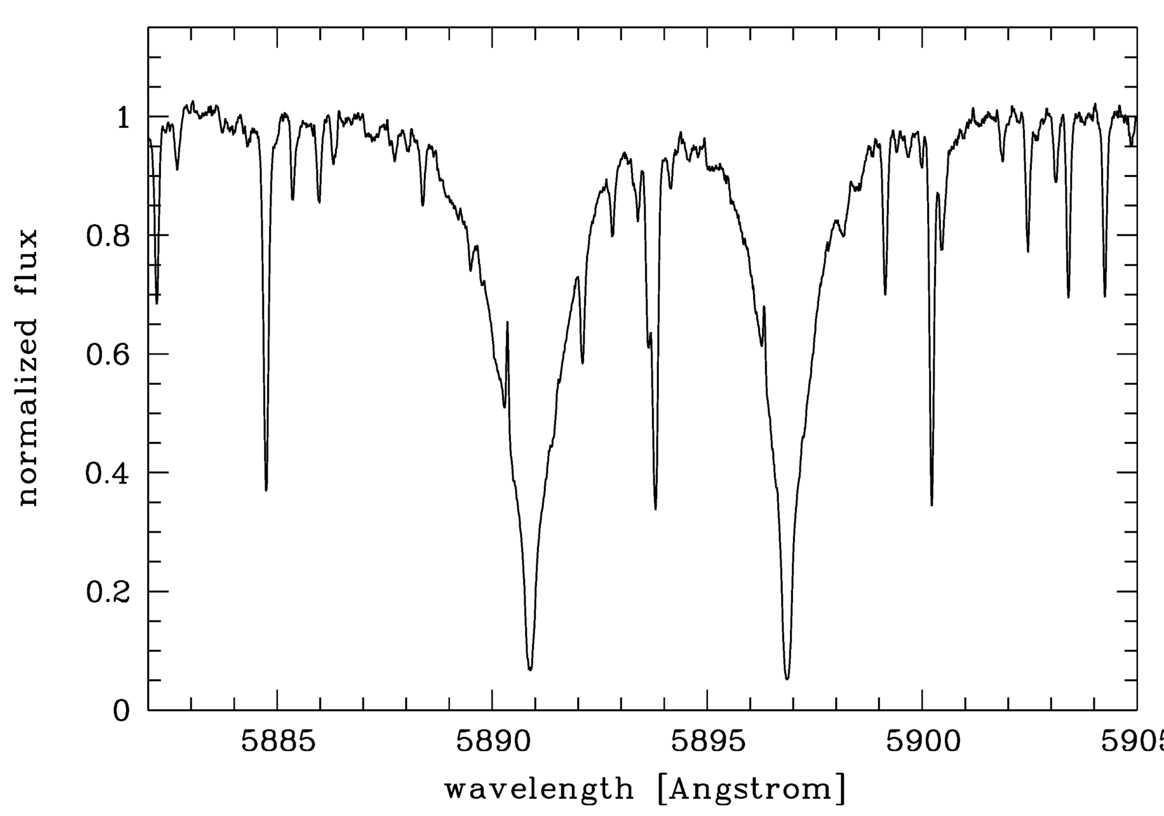

Fig. 6: A representative spectrum of the time-series transit observation of XO-2b with PEPSI. Shown is the sodium doublet line of the host star.

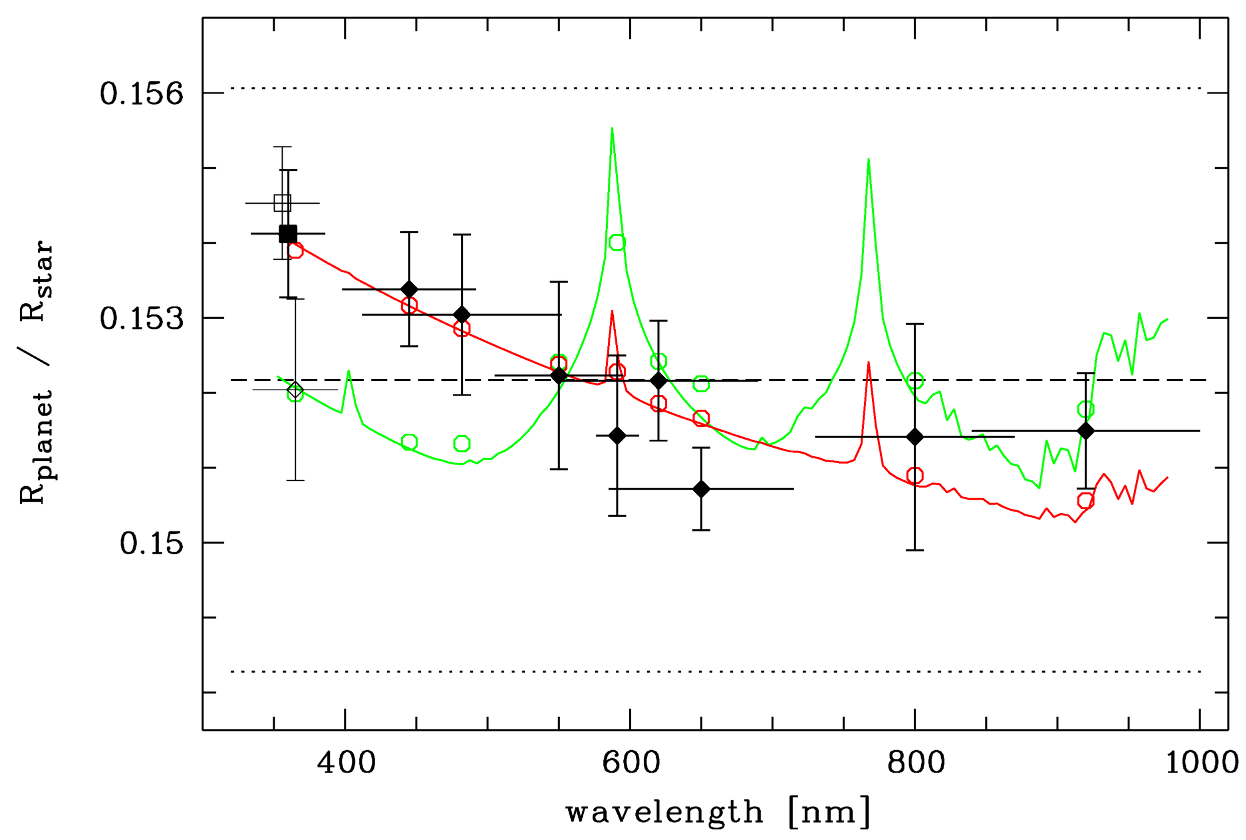

Fig. 4: Broad-band transmission spectrum of HAT-P-32b. The U band data point was obtained from the U band LBC transit light curve. The data confirm the MODS spectrum of the same planet.

LBTO users meeting, Florence, June 20-23,2017