Planetary transit observations at the University Observatory Jena: TrES-2

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Abstract

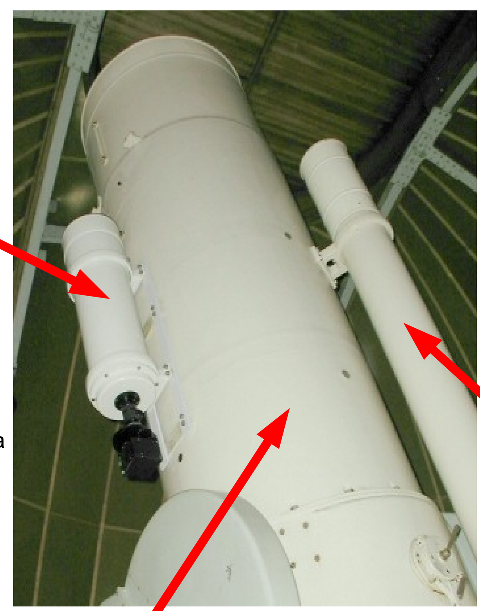
We report on observations of several transit events of the transiting planet TrES-2 with a 25 cm telescope of the University Observatory Jena.
Between March 2007 and November 2008 ten different transits and almost a complete orbital period were observed. Overall, in 40 nights of observation 4291 exposures (in total 71.52 h of observation) of the TrES-2 parent star were taken. With the transit timings from all available TrES, Transit Light Curve (TLC)-Project and Exoplanet Transit Database - data including our own ten transits we find that the orbital period is slightly smaller than the previously published value. We present new ephemeris for this transiting planet.
Furthermore, we found a second dip after the transit which could either be due to a blended variable star or occultation of a second star or even an additional object in the system.
Our observations will be useful for future investigations of timing variations caused by additional perturbing planets and/or stellar spots and/or moons.

Since 1962 the Friedrich-Schiller-University Jena operates an observatory. It is about 10 km to the west of Jena on a plateau (close to the small village Großschwabhausen) and offers for its location in Central Europe decent conditions for optical astronomy.

Instruments and Observations

We have three telescopes available, a 90 cm reflector, a 20 cm refractor and a 25 cm Cassegrain telescope (see box on the right side).
Our transit observations were carried out with the 25 cm Cassegrain view finder mounted picky-pack on the tube of a 90 cm telescope equipped with the optical CCD-camera CTK (*Cassegrain Teleskop Kamera*, see camera information box). For our TrES-2 observations, started in March 2007, we used 40 nights since March 2007 to November 2008. All TrES-2 observations were taken in I-band with 60 s exposure time. The results are presented in the box at the bottom.

The Telescopes



View Finder

Focus:	Cassegrain
Diameter:	25 cm
Focal length:	2250 mm
f/D:	9
Instrument:	CCD-Camera CTK

Telescope

Focus:	Schmidt / Nasmyth
Diameter:	60 cm / 90 cm
Focal length:	1800 mm / 13500 mm
f/D:	3 / 15
Instrument:	CCD-camera / spectrograph STK / FIASCO

Guide Scope

Focus:	Refractor
Diameter:	20 cm
Focal length:	3000 mm
f/D:	15
Instrument:	CCD-camera RTK

CTK - *Cassegrain-Teleskop CCD-Kamera*

Fabricator:	Finger Lake
Type:	IMG 1024S
Detector:	CCD TK1024 (Tektronix)
Pixel:	1024 x 1024 (24 µm)
Pixel scale:	(2.2065 ± 0.0008)"/Pixel
Field of view:	37.7' x 37.7'
Filter:	B, V, R, I, z
Focus:	Cassegrain

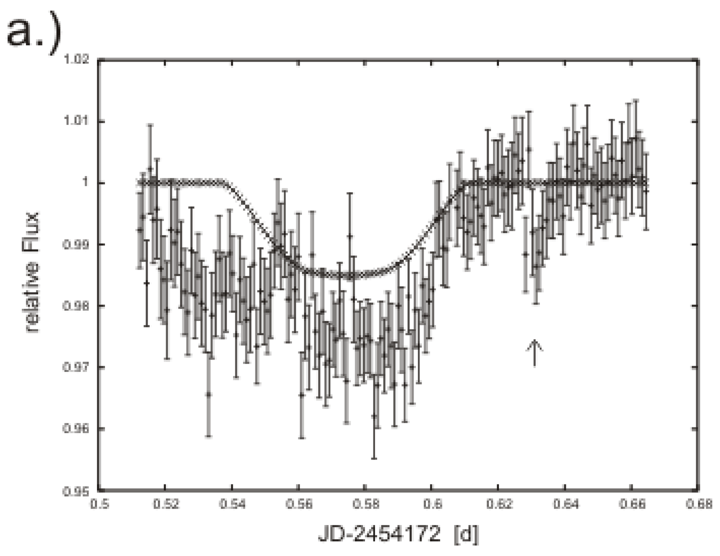
Methods

- A differential photometry algorithm by Broeg et al. (2005) was used to determine the differial magnitudes.
- A detrending algorithm called "Sys-Rem" (Tamuz, Mazeh & Zucker 2005, implemented by Johannes Koppenhöfer) was used to remove systematic effects
- An analytic light curve taking limb darkening into account was applied to fit the data of TrES-2
- The transit timing residuals were calculated using the ephemeris given by Holman et al. (2007): T_c = **(2453957.63479 + E*2.470621) d**

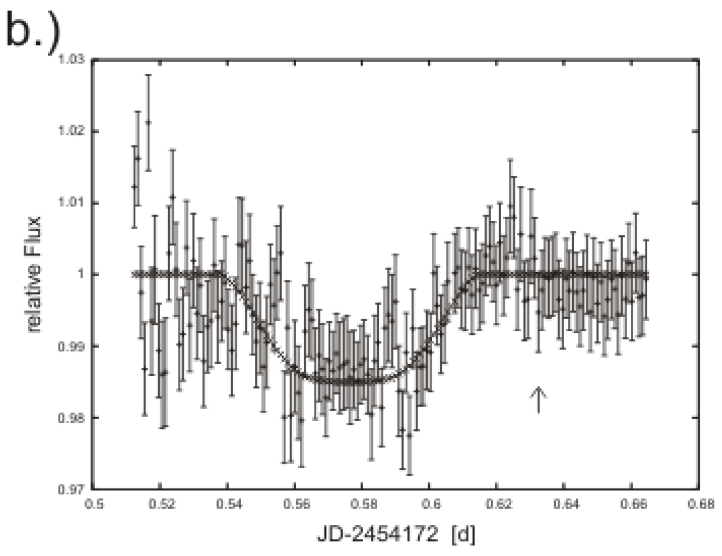
Results

The following figures show the same light curves of TrES-2 (a & b and c & d) before and after using Sys-Rem.

a.)



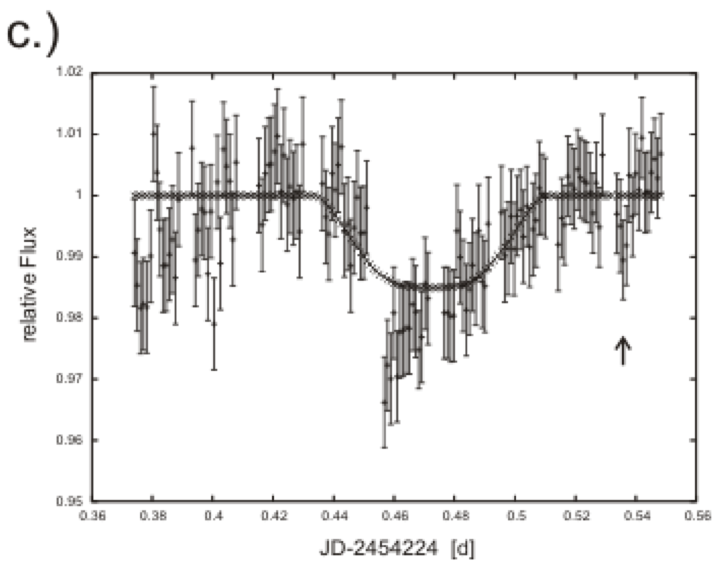
b.)



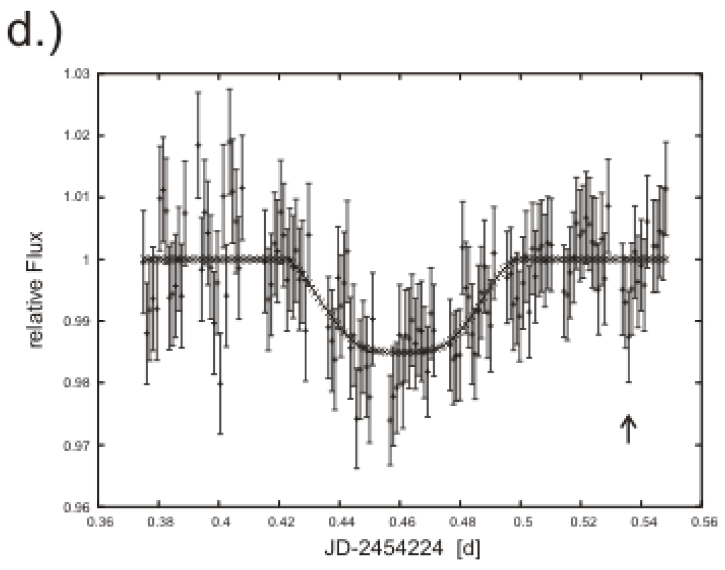
In our first observations of a transit of TrES-2 we could detect a second dip after the end of the transit. An indication of the existence of the dip is published by O'Donovan et al. (2006) in a TELAST *R*-band light curve in their Fig. 1, where one can clearly recognize a brightness drop.

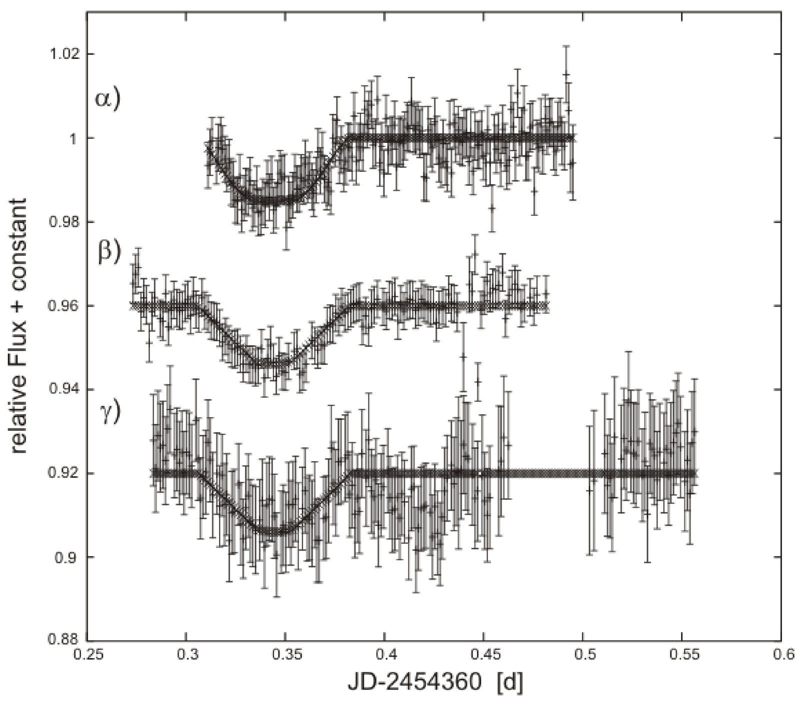
We observed ten different transits. We could detect the second dip only after our first two transit observations. After using Sys-Rem the dip disappeared for the first transit (a & b) while it became stronger for the second transit (c & d).

c.)

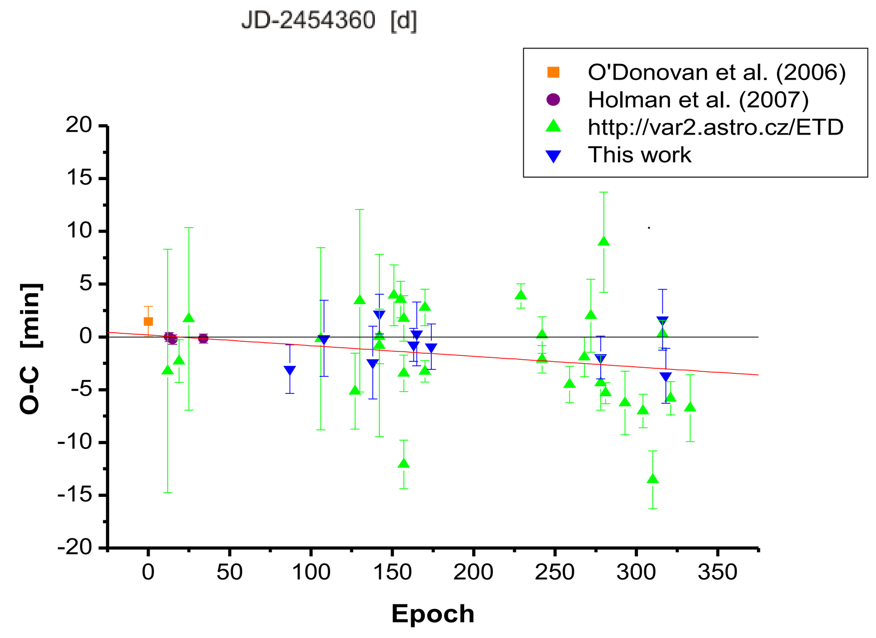


d.)

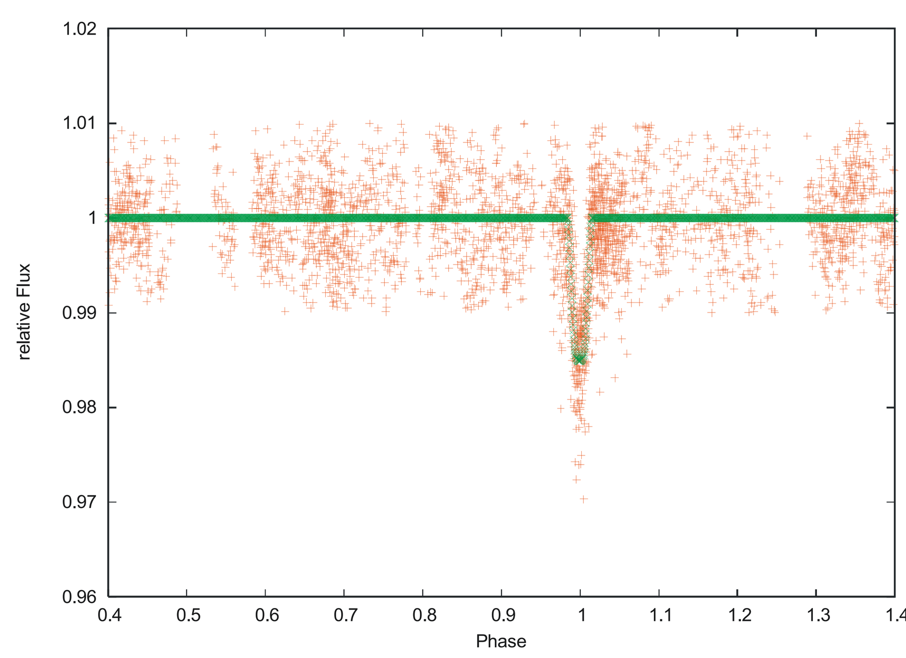




Because of the good weather conditions on 2007 September 16 we observed a transit of TrES-2 with three different telescopes to get three independent measurements:
α) I-band photometry from the Jena University Observatory with a mean photometric precision of 0.006 mag
β) R-band observations from the Wendelstein Observatory of the university of Munich. For these observations the mean photometric precision is 0.005 mag
γ) White light observations of an amateur astronomer (M.R.). We reached a photometric precision of 0.01 mag which is sufficient to detect a transit



Transit timing residuals for TrES-2. The black line shows the ephemeris given by Holman et al. (2007). We found a negative trend in this (O-C)-diagram. Thus, we refine the ephemeris. The best fitting line is plotted in red.

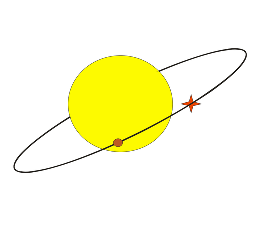


More than 3000 individual observations of TrES-2 from March 2007 to November 2008 calculated in one phase according to the updated ephemeris: T_c **=(2453957.63492 + E*2.470614) d**

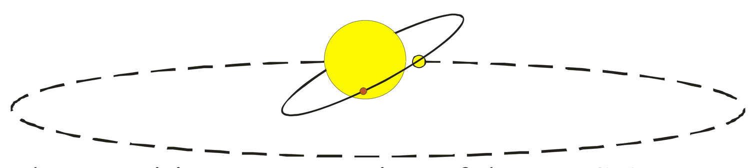
(Raetz et al. 2009b)

Possible explanations

1. A nearby variable star:
A faint object could be within the aperture when doing the photometry. If this object is variable, it could produce a dip.

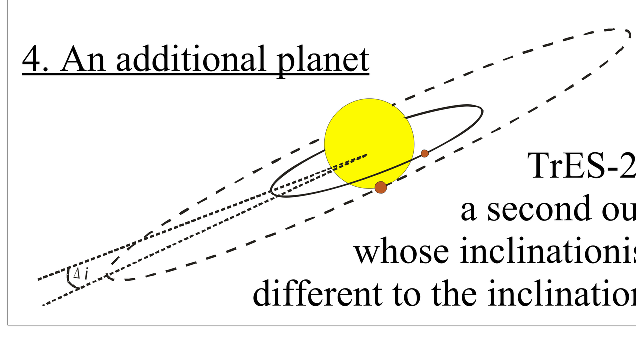


2. Background star:
Origin of the dip by transiting a stationary background giant with a very low projected separation to the TrES-2 parent star. Both stars cannot be separated visually.



3. Companion:
Origin of the dip by transiting a companion of the TrES-2 parent star (difference in inclination exaggerated).

4. An additional planet



TrES-2 with a second outer planet whose inclinationis only minimally different to the inclination of the orbit of TrES-2.

Discussion and Outlook

Using a 25 cm Cassegrain telescope equipped with the optical CCD camera CTK of the University Observatory Jena we observed several transit events and almost a complete orbital period of the known exoplanet TrES-2.
We determined the orbital period to be slightly smaller (~ 0.6 s) than previously expected.
The mean photometric precision of the V = 11.4 mag star is 0.007 mag and the precision in the determination of the transit times is ~ 0.0017 d. This allows us to register transit time variations of around 150 s. The timing residuals are consistent with zero within the measurement errors. We did not find any indication of timing anomalies caused by additional planets or moons.
In our first observations of a transit of TrES-2 we could detect a second dip after the end of the transit. We tried to explain its existence. Four different theories have been created: a nearby variable star or a blended eclipsing binary, an additional planet in the system, a transit over a background star or a transit over a wide companion of the TrES-2 host star after the actual transit is finished. Up to now none of these theories could be rejected or confirmed as a definitive solution.
We will continue observing TrES-2 to confirm the existence of the dip and search for transit time variations for the next few years to decades. We are also working on methods to improve the precision of our transit times.
This year we will start our own search for planetary transits where we monitor different regions of young open clusters with our new CCD camera for the Schmidt focus of the 90 cm reflector. This camera will have a smaller pixel scale and a higher sensitivity. Our transit observations will benefit strongly from the new camera.