New transit observations of WASP-12 b

G.Maciejewski[1], D.Dimitrov[2], D.Kjurkchieva[3], Ł.Bukowiecki[1], D.Puchalski[1]

[1] Centre for Astronomy, Faculty of Physics, Astronomy and Informatics,
Nicolaus Copernicus University, Grudziadzka 5, 87-100 Torun, Poland; gm@astri.umk.pl

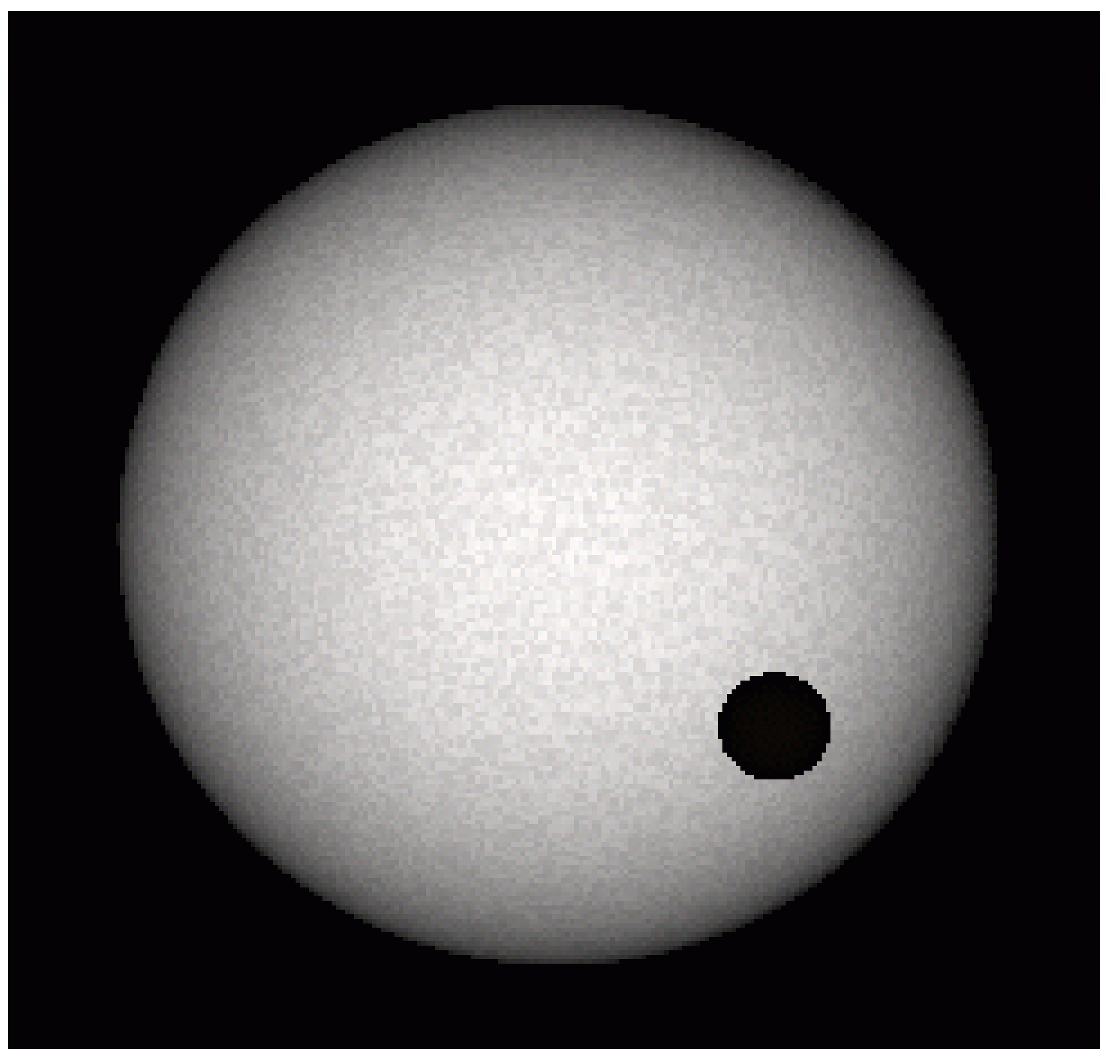
[2] Institute of Astronomy and NAO, Bulgarian Academy of Sciences, Sofia, Bulgaria

[3] Department of Physics, Shumen University, 9700 Shumen, Bulgaria

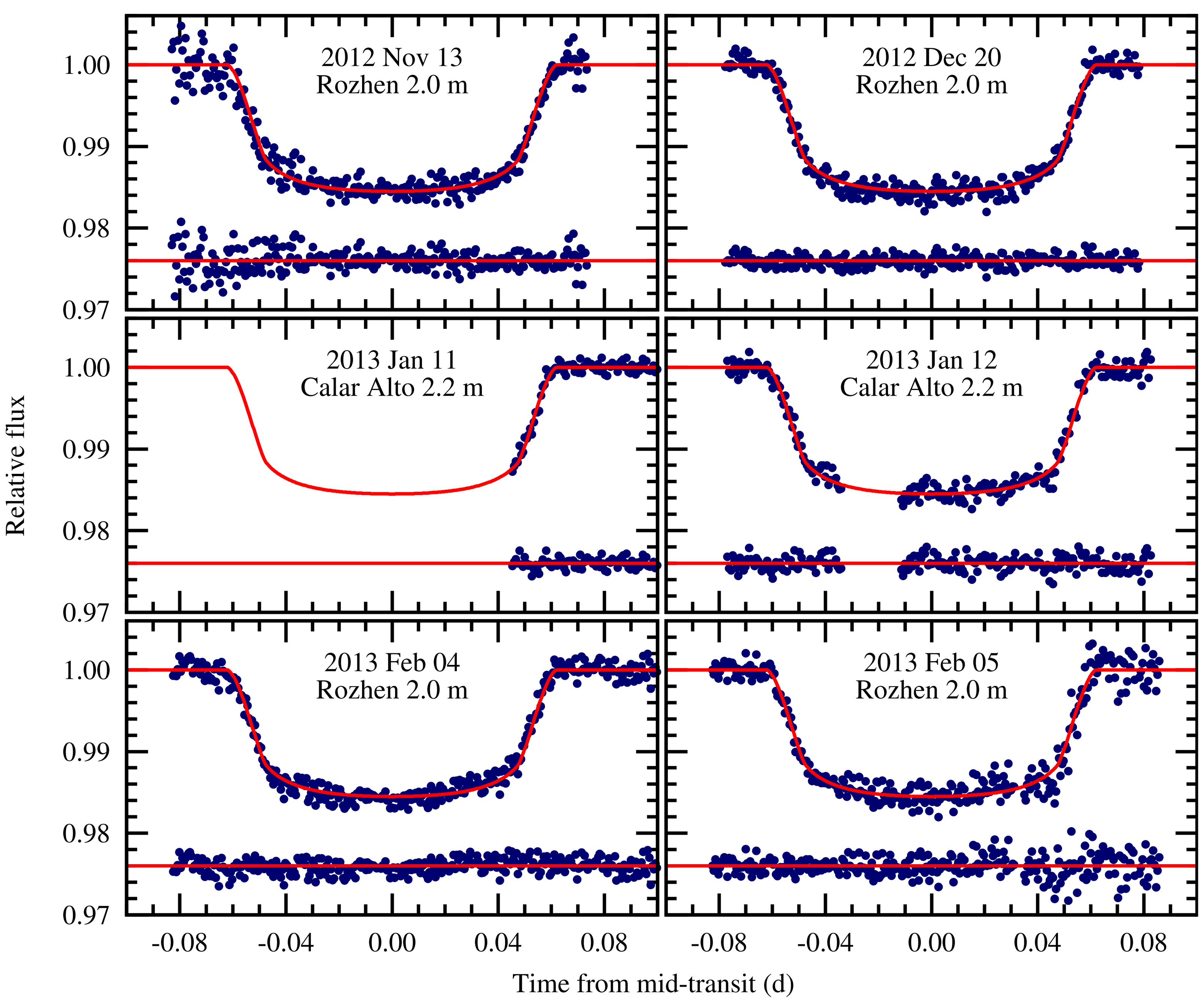
Abstract: The transiting extrasolar planet WASP-12 b was announced to exhibit a sign of variations in transit timing. The postulated signal has a period of 550 days and a semi-amplitude of 2 min. Joint analysis of the radial velocities and transit timing resulted in a two-planet model which fits observations much better than a single-planet model. This finding allows us to advance the hypothesis that WASP-12 b is accompanied by additional, less massive planet on a tight orbit. Statistical studies of hot Jupiter candidates in the Kepler sample show that these planets are rare in multi-transiting planetary systems. Solitariness of hot Jupiters is postulated to be a result of the dynamical evolution of their planetary systems. The WASP-12 system would be an interesting outlier which would be challenging for theories of evolution of planetary systems. We present new observations gathered in the observing season 2012/2013 that confirm the transit timing signal and refine its characteristics.

1. WASP-12 system

The transiting exoplanet WASP-12 b (Hebb et al. 2009) orbits its quiet G-type host star every 1.09 d (*right*: an artist conception of the WASP-12 system in a transit). Its bloated radius of 1.90 ± 0.09 $R_{\rm Jup}$ may have origin in the dissipation of tidal energy that is driven by a possible non-circular orbit. However, the orbit of WASP-12 b is expected to be circularised on short timescales, so any non-zero eccentricity must be sustained by gravitational perturbations from an additional planet. Observations of occultations show that the planetary orbit must be very close to circular one or its eccentricity is masked by the specific value of longitude of periastron which may be close to 270°. The additional planet in the system could affect the orbital motion of the transiting planet whose transit timing would exhibit a departure from a linear ephemeris. This so-called transit time variation (TTV) method has already been used for confirming the planetary nature of systems with multiple transiting planets and discovering additional planetary companion which cannot be detected with other techniques. All these discoveries are based on data acquired with the *Kepler* space telescope and to our knowledge no confirmed TTV signal has been detected from the ground so far. Our first results obtained for WASP-12 b show a sign of a TTV signal for WASP-12 b (Maciejewski et al. 2011). Being encouraged by this result, we organized a multi-site campaign for WASP-12 b transit timing in 2009-2012. Using high-quality data, we have detected a TTV signal which has a period of ~550 days and a semi-amplitude of 2.0 ± 0.4 min (Maciejewski et al. 2013). Joint analysis of the available radial velocities (RVs) and transit and occultation timing resulted in a two-planet model which fits observations much better than a single-planet model. The model predicts the existence of a second planet which has a mass of 0.1 $M_{\rm Jup}$, an orbital period of 3.6 d, and a surprisingly high eccentricity of 0.29. The numerical simulations show however that such a system is stable in long timescales. New observations will be used to better constrain parameters of the additional planet, to refine its ephemeris to search for its transits, and to study the two-planet system dynamics in detail.

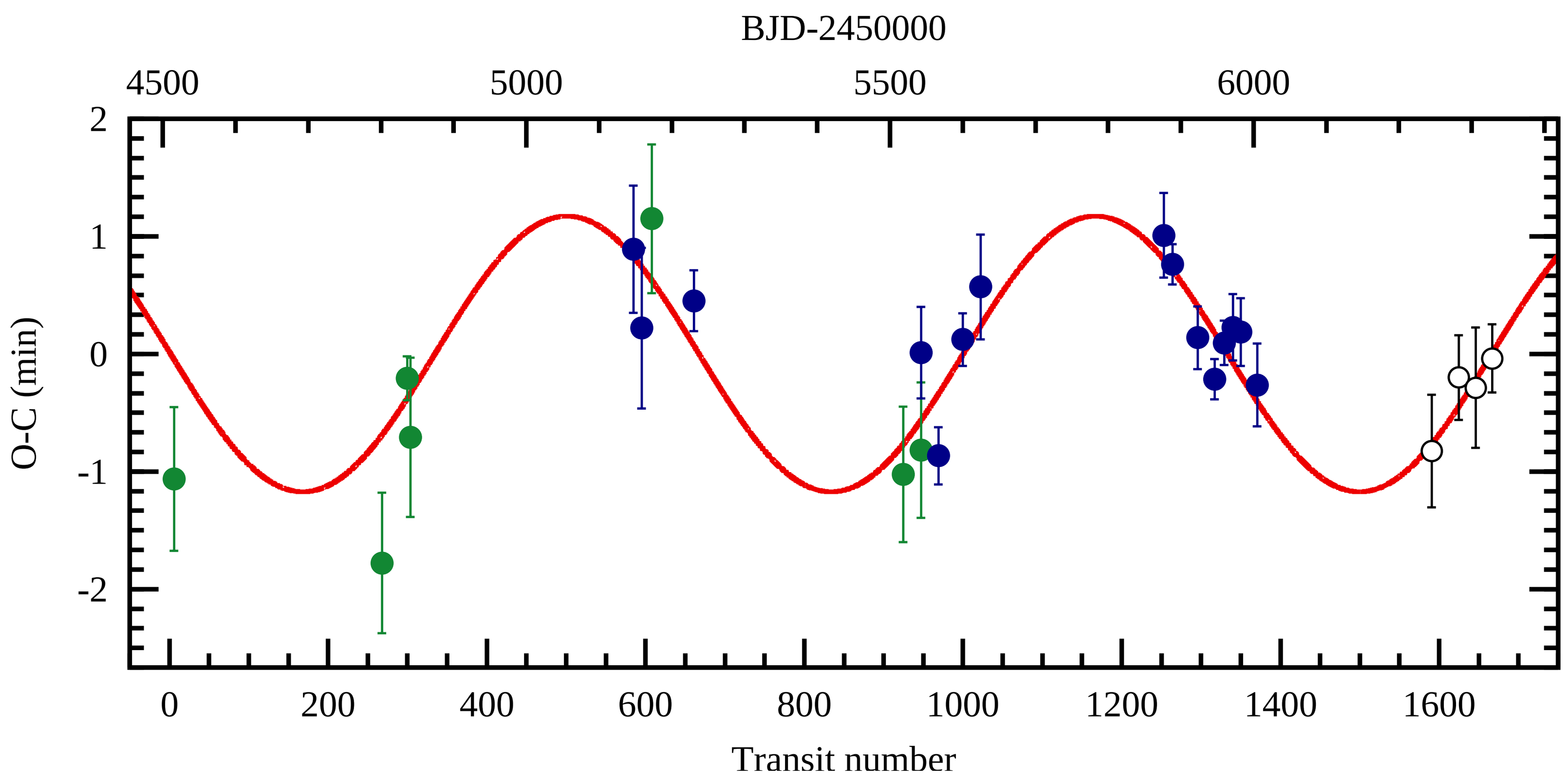


2. New high-quality data



In the 2012/2013 observing season, we acquired six transit light curves with the 2.0-m Ritchey-Chrétien telescope at the National Astronomical Observatory at Rozhen (Bulgaria) and the 2.2-m telescope at the Calar Alto Observatory (Spain). Both instruments were significantly defocused to reduce flat-fielding noise and decrease the amount of time lost due to CCD readout. Fluxes were obtained with differential aperture photometry against comparison stars available in the field. The aperture size was optimised to achieve the lowest data point scatter. The data were modelled with the Transit Analysis Package (Gazak et al. 2012) that employs the Markov Chain Monte Carlo (MCMC) method, with the Metropolis-Hastings algorithm and a Gibbs sampler, to find the best-fitting parameters based on the transit model of Mandel & Agol (2002). To estimate uncertainties, wavelet-based techniques (Carter & Winn 2009) are used to take into account correlated noise. The *photometric noise rate* (the *rms* per minute of exposure) of the light curves is between 1.0 and 1.3 mmag. Mid-transit times are determined with errors between 17 and 31 s.

3. Transit timing



The new mid-transit times (open symbols) were combined with the high-quality literature data (green points) and values redetermined from Maciejewski et al. (2013; blue points). Individual light curves of consecutive transits (within a few epochs) were combined to achieve better timing precision. The new data confirm the claimed TTV signal (red line) and allow its characteristics to be refined. Statistical studies of hot Jupiter candidates in the *Kepler* sample show that these planets are rare in multi-transiting planetary systems. In this context, the WASP-12 system would be an interesting outlier which would be challenging for theories of evolution of planetary systems. Some hot Jupiters in the *Kepler* sample exhibit TTV signals. In this context, the possible discovery of the TTV signal for WASP-12 b is not a complete surprise, though it is a breakthrough in the TTV studies from the ground. The WASP-12 system may be in a different category of hot Jupiters accompanied by a nearby lower-mass planets. This category remains explored because very hot Jupiters are rare in the *Kepler* sample. The brightness of the host star ($V = 11.8$ mag) is its undoubted advantage in the era of *Kepler* discoveries. It allows follow-up observations to be undertaken to verify origin of the timing variation with independent observational techniques: precise radial velocities and possible transit detection.

References

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