Is WASP-12 b falling onto its host star?

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1. About the WASP-12 system

It belongs to a small group of planetary systems with giant planets on extremely tight orbits. The orbital period of the transiting planet WASP-12 b is only 1.09 d long (Hebb et al. 2009). At the time of discovery, it was found to be one of the most intensely irradiated planets. The planet is a bloated hot Jupiter with an effective radius of 1.9 R_{Jup} (Maciejewski et al. 2013) and a mass of 1.4 M_{Jup} (Hebb et al. 2009). The planet's proximity to the star results in a high equilibrium temperature of 2500 K, thus encouraging numerous studies on the properties of the planetary atmosphere, as well as planet-star interactions.

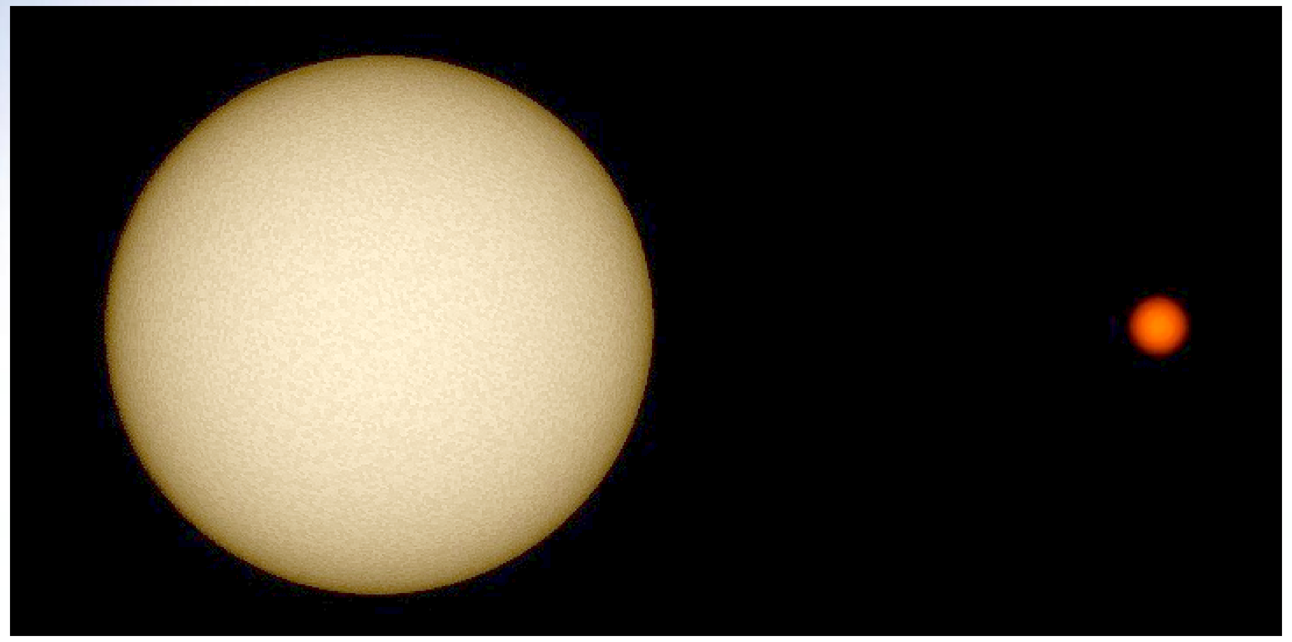

Fig.1. Schematic visualisation of the WASP-12 system. The orbital distance and bodies' sizes are in the scale.

2. Departure from a linear ephemeris

We detected the apparent shortening of the orbital period with the method of precise transit timing (Maciejewski et al. 2016). This phenomenon could be a manifestation of the orbital decay due to tidal dissipation inside the star (e.g Levrard et al. 2009, Essick & Weinberg 2016) or could be a part of the long-term periodic variations produced by apsidal precession of a slightly eccentric orbit (e.g., Ragozzine & Wolf 2009). The latter scenario is disfavoured by new transit and occultation timing (Patra et al. 2017). As it is presented in Fig. 2, our new transit observations, acquired between 2016 and 2018, follow the quadratic ephemeris very well. The high decay rate could be explained if WASP-12 were a subgiant in which the tidal dissipation is boosted by several orders of magnitude due to nonlinear wave-breaking of the dynamical tide near the star's centre (Weinberg et al. 2017).

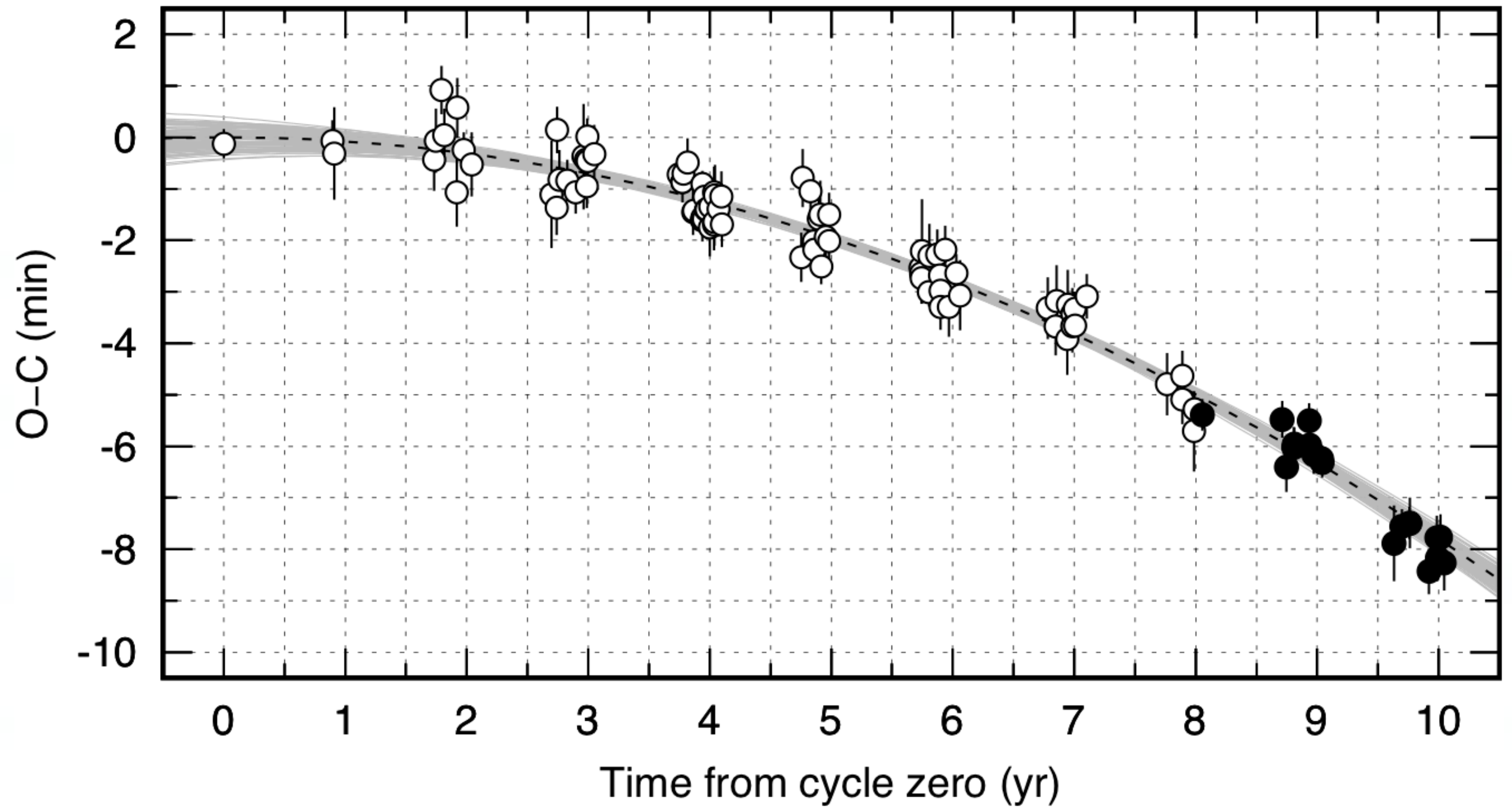

Fig.2. Timing residuals against the linear ephemeris for WASP-12 b over a course of 10 years of observations. Our new observations are marked with dots, while the redetermined literature ones are plotted with open circles. A dashed line shows the best-fit quadratic trend in transit times. The ephemeris uncertainties are illustrated by grey lines that are drawn for 100 sets of parameters, randomly chosen from the Markov chains. Taken from Maciejewski et al. 2018 (AcA, in prep.).

3. The alternative scenario

Our analysis of timing data together with high precision Doppler measurements from Knutson et al. (2014) and Bonomo et al. (2017), supplemented by over a dozen data points which we have collected with HARPS-N (Maciejewski et al., in prep.), allowed us to identify the alternative scenario that could explain the departure of transit times from the linear ephemeris. We found a unique solution with an additional planet, whose mass is about 17 Earth masses and the orbital period is 3.2 d (Fig. 3). This additional planet could perturb the orbital motion of WASP-12 b that manifests as the apparent orbital decay – a part of a decades-long cycle. The existence of this planetary companion seems to be marginally supported by the Doppler measurements with false alarm probability of 1%. Our dynamical model predicts that the system could be almost coplanar and the additional planet would be likely to transit the host star. However, our observations reveal no sign of such transit signatures deeper than 0.7 mmag.

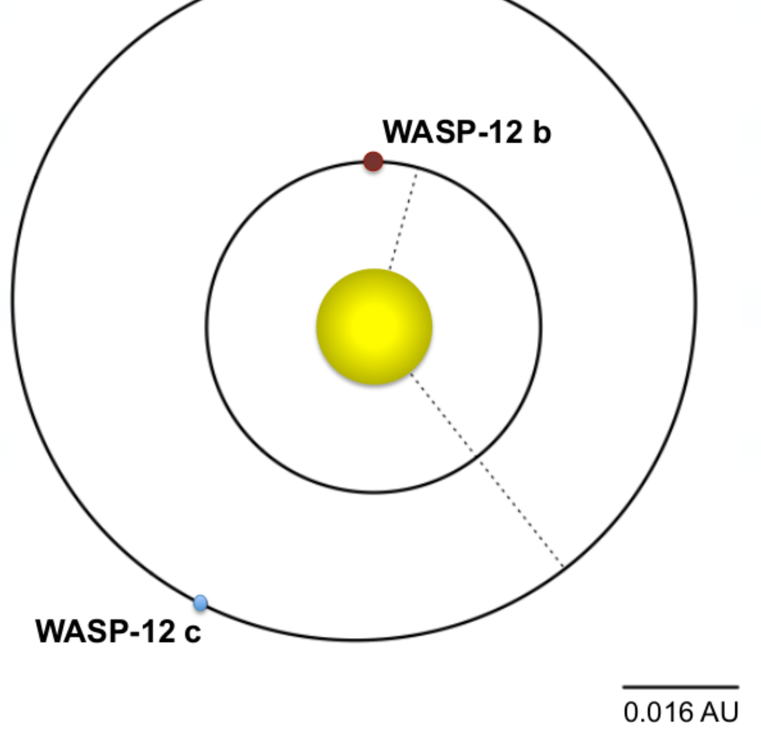

Fig.3. Possible architecture of the WASP-12 system with the hypothetical Neptune-mass planet which could perturb the orbital motion of the known transiting planet WASP-12 b.

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Acknowledgements: We acknowledge the financial support from the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.