How does the nodal precession affect observations of hot Jupiters around A-type stars?

*Noriharu Watanabe[1], Norio Narita[2]

1. The Graduate University for Advanced Studies, SOKENDAI, 2. Astrobiology Center

More than 4,000 exoplanets have been found. Even though most of these discovered exoplanets are orbiting around Solar-type (F/G/K type) stars, there are also a small number (~20) of exoplanets, most of them are hot Jupiters, around hot (B/A type) stars. Despite the small number, we have known that they tend to have a wide range of projected spin-orbit obliquities, the apparent angle between the stellar spin axis and the planetary orbital axis. Because hot stars are rapidly rotating in general, they make themselves more oblate. When a planetary system satisfied these two conditions, the misaligned orbit and the flatten host star, its orbital nodal precession occurs. The nodal precessions of two planets have been reported so far: Kepler-13Ab (Szabó et al. 2012) and WASP-33b (Johnson et al. 2015), both of which are orbiting around A-type stars. Especially, Watanabe et al. (2020) found that the nodal precession period of WASP-33b is ~840 years and this hot Jupiter transits in front of the host star for only ~20% of the whole precession period. In this research, we focused that how the nodal precession affects observations of hot Jupiters around A-type stars by theoretical models.

Zhou et al. (2019) estimated the occurrence rate of hot Jupiters around A-type stars 0.26±0.11% from the TESS sample, which is a little lower than rates of F/G type stars (F-type star: 0.43±0.15%, G-type star 0.71±0.31%). However, this previous study did not consider orbital nodal precession around A-type stars. Thus, we have calculated how the occurrence rate of hot Jupiters around A-type stars changes when the precession is applied. First, we formulated the ratio between the period for transiting in front of a host star and the orbital nodal precession period (ε). Then, we simulated 100,000 models of planetary systems of a hot Jupiter and an A-type star. In this simulation, we set values of essential parameters randomly based on the detected values of hot Jupiters around A-type stars. In general, the possibility of planetary transit almost equals to the ratio of the sum of the ratio of the stellar radius to the semi-major axis to the number of samples, but the possibility should be calculated by the sum of ε when the orbits are precessing. However, we derived that the possibility of planetary transit of hot Jupiters is 17.8% whether we consider the nodal precession or not. Therefore, the nodal precession does not affect the occurrence rate of hot Jupiters around A-type stars.

We also calculated how many orbits of hot Jupiters enter and leave in front of hot stars for ten years. First, we derive we computed the precession speeds of 100,000 models using equations from Barners et al. (2013) and Iorio (2010). Then, we simulated the ten-year-changes of impact parameters of all simulated models. As a result, ~2,500 models begin to transit their host stars as viewed from the Earth, other ~2,500 models finish transiting, and ~120 planetary orbits pass through their stellar disks for ten years. We have also found that there are a few hot Jupiters whose trajectories will depart from their stellar disks even though their impact parameters are almost zero. This simulation shows that the transit possibility is stable but perhaps a part of detected hot Jupiters will be disappeared after ten years later. Consequently, we should observe a hot Jupiter around a hot star continuous by Doppler tomography, a method to measure projected spin-orbit obliquity and impact parameter, and estimate how its transit trajectory is shifting and when it will end to transit.

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