Atmospheric Dynamics on Non-Synchronized Tilted Exoplanets: Implications on Observed Thermal Light Curves

*Kazumasa Ohno[1], Xi Zhang[2]

1. Department of Earth and Planetary Science, Tokyo Institute of Technology, 2. Department of Earth and Planetary Science, University of California Santa Cruz

Various theoretical studies of atmospheric dynamics have investigated the dynamical structure on close-in synchronized exoplanets and succeeded to explain the phase curve observations. As the planets are farther away from their central stars, they are not likely to be tidally locked. Recent studies also begin to examine the atmospheric dynamics on non-synchronized exoplanets (e.g., Showman et al. 2015); however, they assume the planetary obliquity, the angle between orbital normal and planetary spin axis, is zero that is usually not true for non-synchronized planets.

In this study, we investigated the atmospheric dynamics on non-synchronized tilted exoplanets with a 2D general circulation model. We find that the temperature structure is considerably different from that on the synchronized exoplanets. Non-zero obliquities induce the temperature structure that is dominated by diurnal mean insolation if the radiative timescale is longer than rotation period but shorter than orbital period. The temperature is dominated by annual mean insolation if the radiative timescale is longer than both rotation and orbital periods. Seasonal variation as function of orbital phase is analyzed. We also predict the shape of observed thermal light curves for non-synchronized tilted exoplanets. Our prediction suggests that the amplitudes of light variation for high-obliquity exoplanets might be several times larger than that for the low-obliquity exoplanets but the differences depend on the parameters such as the radiative timescale and the line of sight from an observer. Furthermore, we find that the thermal light curves for tilted exoplanets might have a peak after the secondary eclipse if they are transiting, whereas for synchronized planets the phase curve peak always occurs before the secondary eclipse. Consequently, our results suggest that the planetary obliquity has the crucial impacts on the interpretations of observed phase curves for non-synchronized exoplanets.

Keywords: Exoplanets, Atmospheric Dynamics, Thermal Light Curve