Long-term observation of planetary-scale waves in the Venus cloud top layer with ground-based telescopes and AKATSUKI/UVI

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On Venus, two types of planetary-scale waves, ~4-day Kelvin and ~5-day Rossby wave, were observed at the ~70 km cloud top with zonal wavenumber 1. These waves could contribute to the formation of planetary-scale features seen in 365 nm unknown absorption band, and they might be a candidate of momentum transporter to maintain the super-rotation.

During the Pioneer Venus and Venus Express mission periods, the observed waves changed one to another in every observational period. However, since the spacecraft was operated in the polar orbits nearly fixed inertial space, there were significant data gaps over half of the Venusian year (one Venusian year is ~224 Earth days) between one and next observational period.

The purpose of this study is revealing the appearance (disappearance) and transient behavior of the planetary-scale waves on Venus. For this purpose, we developed an image analysis method for measuring latitudinal relative brightness from the equatorial to mid-latitudinal regions and deducing the rotation period.

We conducted ground-based observations over half Venusian year (one Venusian year is 224 days) by using 1.6-m Pirka telescopes in OP2015 (2015/04/21--07/17), OP2017A (2017/01/03--02/19), and OP2017B (2017/04/23--09/10). Additionally, we analyzed Venus images obtained by Ultraviolet Imager (UVI) onboard AKATSUKI. UVI observation covered partially the same periods of the ground-based as OP2017A (2016/11/06--2017/03/02) and OP2017B (2017/06/15-- 09/31). Finally, Over 300 days continuous data from December 2016 to September 2017 was retrieved with only 50 days data missing interval.

To capture the continuous variability in periodicity through the observational periods, we made sub-dataset with ±14 days shifting window and stepped it with the 1-day interval, and Lomb-Scargle periodogram analysis was conducted for each sub-dataset. Three latitudinal bands of EQ (10S–10N), SM (50S–30S), and NM (30N–50N) were investigated, and it was validated that ground-based and space-based data has a high agreement and directly comparable.

Two prominent modes with 3.5–4.0-day and 5-day period were confirmed in our results. The 3.5–4.0-day modes were observed mainly and tended to survive for a longer time. In contrast, 5-day mode sporadically appeared and sometimes last longer than 30 days. Zonal wind velocity at the cloud top was estimated by the cloud-tracking method (Horinouchi et al. [2017]). The measured zonal mean-wind velocity was ~100 m/s (4.4-day period rotation at the equator) and observed modes could be classified as faster (westward) propagating wave against mean-winds or slower (eastward) propagating wave. Following previous studies (e.g., Del Genio and Rossow [1990]; Kouyama et al. [2015]), the faster mode should be equatorial Kelvin

wave, and the slower mode was suggested as Rossby wave in mid-latitudes.

The wave transient occurred within a sub-Venusian year, and the transient behavior could be classified into two types. One is completely mode transient from 4-day to 5-day with ~20 days interval. The other one is continuous periodicity change from 4-day to 5-day, where 4-day mode was continuing, and double-mode was observed at the moment. Since the zonal mean-wind during the observational periods were almost constant, the transient of planetary-scale waves might not be controlled by the zonal mean-wind velocity near the cloud top as proposed by Kouyama et al. [2015]. The periodicities in the fluctuations of equatorial zonal winds were distinctly different from that in the brightness variation. One of the interpretation is that 5-day wave in mid-latitudes has the more significant amplitude of fluctuating winds than 4-day wave at the equator. In parallel, another possible explanation is acceptable that the 4-day wave observed with planetary-scale features reflects at a lower altitude than the that of the 5-day wave measured by mesoscale cloud tracking.

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