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Ground-based Observation of planetary lightning flashes with Photomultiplier tube

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Abstract

Lightning in planetary atmospheres are generated by the convections, so the detection of lightning can be used to deduce the atmospheric dynamics and the large-scale structures on other planets. In the case of Jupiter, the lightning flashes have been observed in the dense clouds. Previous studies (e.g. Gierasch et al., 2000; Ingersoll et al., 2000) suggested that zonal jet is driven by small-scale eddies that receive their energy from moist vertical convection which similar to large thunderstorm on the Earth. Although it is difficult to know the vertical convections within the dense clouds, lightning clusters are correlated with the cumulonimbus, and thus lightning observations can be used to investigate the formation of Jupiter's zonal jet structure. In Venus, the existence of Venusian lightning is controversial for 40 years, and the possible generation mechanisms are convection, volcanic, or aeolian triboelectric activity. In the previous study, there are radio wave observations and optical observations by CCD. Although some of the observations have detected lightning, no unambiguous lightning flash events have been detected recently by LAC (Lightning and Airglow Camera) onboard AKATSUKI Venus Climate orbiter (Lorenz et al., 2019). There is no robust evidence of existence the lightning because it is difficult to distinguish between the lightning signal and the electrical noise or other plasma waves, the observation area is limited, and the CCD's sensitivity is not enough for lightning flashes. If we can confirm the existence of Venusian lightning like the Jovian, it could also be an indicator of Venusian atmospheric dynamics.

To reveal the relationship between lightning and atmospheric dynamics of Jupiter and Venus, we have developed the Planetary Lightning Detector (PLD), which is the high-speed and high-sensitive lightning detector mounted on a 1.6-m ground-based telescope "Pirka" by using a photomultiplier tube to observe the planetary lightning. Pirka telescope, operated by the Faculty of Science, the Hokkaido University, is primarily dedicated to observations of the planets of the Solar System. Using this telescope we can obtain an observation period at least one hour per day for several months, longer than the previous studies. We can obtain the light-curve of flash events with a sampling rate of >20 $s^{-1}$to distinguish the other flashes and decrease the contamination of dayside light and sky to improve the Signal-to-Noise ratio. We will reveal the concentrate of lightning and its frequency, and then we derive the distribution of a few tens km scale vertical convections. We compare the results

and the variation of wind velocity or cloud distribution to reveal the atmosphere dynamics.

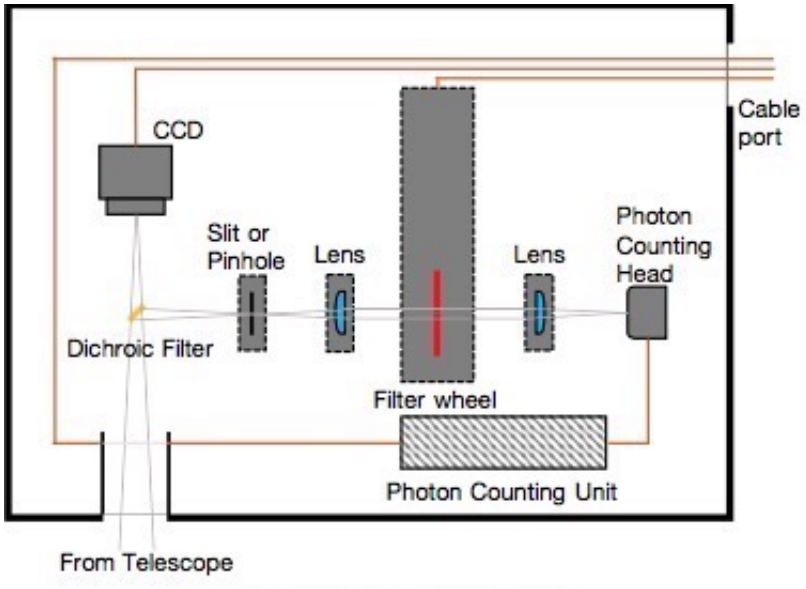

Figure 1: The layout of inside of PLD.

777.4 nm (atomic oxygen) is the predicted strong emission line in the Venus lightning spectra (Borucki et al. 1996). PLD equips narrowband filter (FWHM = 1 nm) of 777 nm. PLD observes the light by using a Photomultiplier tube. The minimum exposure time is 50 microseconds. The maximum time resolution is about $2x10^4$ points/s. PLD's FOV can be changed to 5", 10", 30", 60" pinhole, and 2"x11" slit by using field stops. Slit and pinhole are used for Venus's night-side observation. To obtain the lightning's light curve, we operate the bandpass filter to remove noise and large time scale variation by the atmosphere. We have observed Venus by using PLD from May 2020. In our Venus observation, we could find several possible lightning events having large count values above 4-sigma of the background level. The detection frequency was 3 events per 2000 s observation period. The estimated peak energy of light-curve is about from 8.9×10^7 to 1.4×10^8 J. The calculated event rate is $\sim10^{-11}$ [$s^{-1}km^{-2}$], which is ten times larger than the result of previous study 2.7×10^{-12} [$s^{-1}km^{-2}$] (Hansell et al., 1995). Although, our observation duration is not sufficient to compare with the previous study. we will increase the observation time up to 3 hr in total.

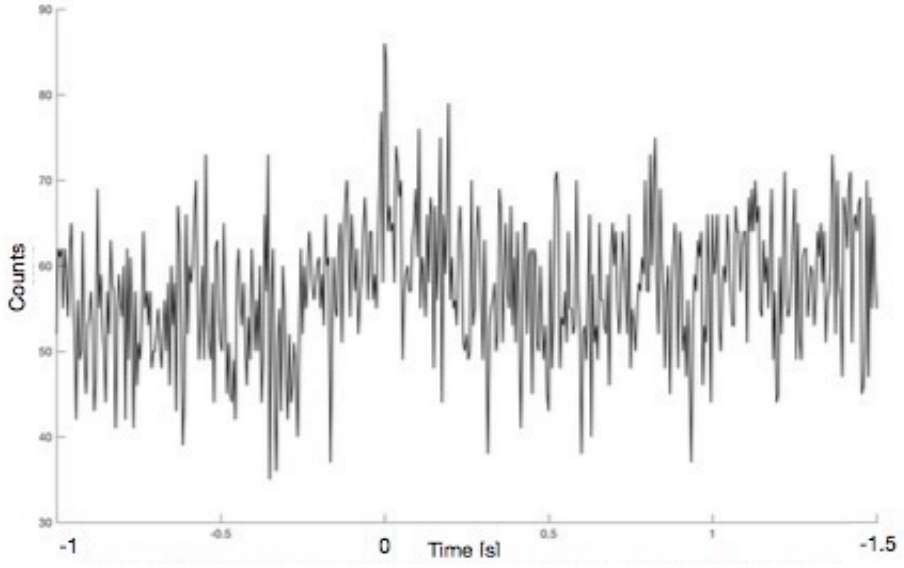

Figure 2: RAW data light-curve of a detected event on 05/18. The triggered time set to 0 s.

In this presentation, we will introduce the newly developed lightning observation instrument PLD and present our observation results obtained from May 2020. We will also show our future coordinated observation with LAC.

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