Visualization of temporal evolution of auroral beads: high spatial-resolution measurement from the ground

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During the early stage of the expansion phase of substorms, discrete auroras with high luminosity are seen to fill the entire sky, which is called auroral breakup. This study focuses on a phenomenon called "auroral beads," which have attracted attention as a precursor of auroral breakup. Auroral beads are bead-like spatial structures of auroras that appear immediately before the auroral breakup. They have a spatial scale of several kilometers to several tens of kilometers, grow while propagating in the longitudinal direction, and eventually form large vortical structures. Based on its magnetic conjugacy and the exponential time evolution of luminosity, plasma instability in the magnetotail is thought to be involved in their formation. However, the specific mechanism has not yet been identified. This is essentially due to the fact that most previous studies have used all-sky cameras with low spatial resolution, which have not been able to capture the details of where and how the auroral beads form. However, by utilizing the new qCMOS camera, more detailed observations will be possible.

This study analyzes a case of auroral beads using a qCMOS camera, which has a higher spatial resolution than conventional all-sky cameras. The qCMOS camera is located in Skibotn, Norway (69.35N, 20.36E), and data obtained during about 15 minutes from 21:30 UT on November 10, 2023 were used for the analysis. As for the geomagnetic activity, a substorm-induced variation of the geomagnetic X component (negative bay) with an amplitude of about 200 nT and an increase in AE index of about 200 nT were observed at Kilpisjärvi, suggesting that the event was associated with a typical substorm event. These data also suggest that the scale of this event corresponds to a small substorm. The camera is equipped with a lens with a field of view of about 70 degrees and a BG3 filter to measure only the prompt emissions. The spatial resolution is 1024 x 576 pixels and the temporal resolution is 20 FPS (Frame Per Second), which enables high-speed imaging of the aurora with a spatial resolution of about 0.1 km in the center of the field of view.

To clarify the spatiotemporal evolution of the auroral bead structure, we have performed mapping and flat-fielding of the images obtained by the qCMOS camera to geographic coordinates, and have analyzed the north-south and east-west zonal keograms, continuous images of the auroral beads, and the temporal variation of the brightness and its standard deviation in the region including the beads. The results show that the brightness increases as the east-west wavenumber of the auroral beads decreases, and grows exponentially until a certain time. The development of the auroral beads was captured from a spatial scale of a few kilometers, which is similar to or less than that of previous studies (Kataoka et al., 2012). The two-stage growth of brightness in the initial stage of the auroral beads was also identified, which is similar to the one seen in Kataoka et al. (2012). In addition, the new findings in this study include the following new points, it was found that a small-scale wave-like structure propagating eastward was recognized in the background-subtracted image from about 5 minutes before the structure of the auroral beads became visible. These wave-like structures may correspond to the seeding for the instability that drives the formation of auroral beads. In the presentation, we will show the temporal evolution of the wavenumber and luminosity of these structures in detail, and then discuss the processes dominating the appearance

and growth of the auroral beads.

Keywords: auroral beads