Supplementary Material

This material contains three supplementary figures.

In Figure S1, we present some photographs taken by John Andersen, an active citizen scientist in Alberta, Canada, showing the isolated proton auroral (IPA) structures of interest in this study. Citizen scientists typically call them "detached green arcs" or "green blobs". The IPA and the main auroral oval are labeled in each photo. These photos were taken from different viewing aspects so that their geometry looks different, but all clearly exhibit the detached nature and the greenish color of the IPA.

In Figure S2, we provide six examples of the combined image maps of AUGSO 557.7 nm and TREx RGB ASI green-channel based on the best-fit altitudes of IPA from triangulation analyses, and demonstrate the gradual change of the best-fit emission altitudes. The overlapping FoV of the two ASIs is presented as an alpha-blending overlay of two images. The triangulation analysis is performed by matching the optical structures in the overlapping FoV of two ASIs and finding the best-fit emission altitudes (Gillies et al., 2017; Liang et al., 2019; 2021). In a nutshell, we test with different emission altitudes and find the one with the highest correlations between the optical structures seen by two ASI. In this study the analysis is done with 5 km altitude resolution. The upper panel of Figure S3 shows the best-fit altitude determined at each time epoch. The bottom panel shows the peak correlation at the best-fit altitude, as well as the correlation coefficient averaged for altitudes at 5 km (asterisk) above and below the best-fit altitude, and that averaged for altitudes 10 km (triangle) above and below the best-fit altitude. For most of the interval of interest (except at the late stage of the event), the correlation generally peaks at > ~0.85 at the best-fit altitude, yet drops to ~0.5 when the altitudes are 10 km away from the best-fit altitude. The appears to be a distinct gap between the ±5 km correlations and the ±10 km correlations. We thus evaluate that the uncertainties of the emission altitude in our analyses are likely no more than several km, presumably within 10 km.

Two caveats are given here. (1) We perform the analysis only on the IPA; the best-fit emission altitude for the IPA is not necessarily the same as that for the main oval auroras, so that the main auroras may appear to be more or less mismatched in some maps. (2) After ~0322 UT, the IPA moved to rather low elevation angles of the AGUSO ASI, and its view is partially blocked by trees at the south-eastern edge of the camera. The above difficulties make the accuracy of the triangulation procedure deteriorate at the later stage of the IPA so that it is not presented here. We assume a constant emission altitude of 135 km after 0320 UT in this study.

Figure S1


IPA
MAO
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IPA
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IPA
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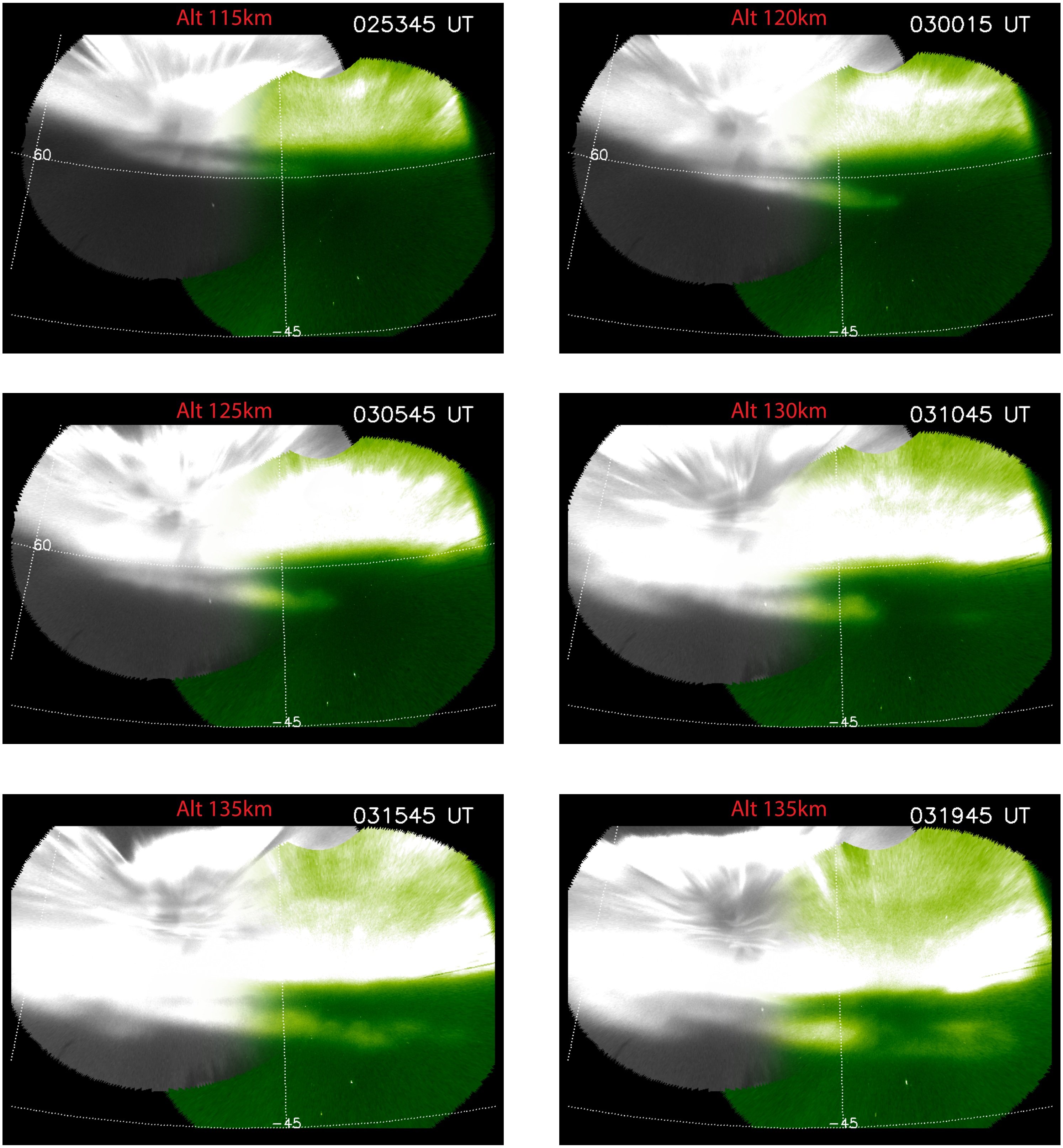

Figure S2. Six examples of the combined image maps of AUGSO and LUCK RGB ASI based on the best-fit altitudes of DGPAS from triangulation analysis. The overlapping FoV of the two ASIs is presented as an alpha-blending overlay of two images.

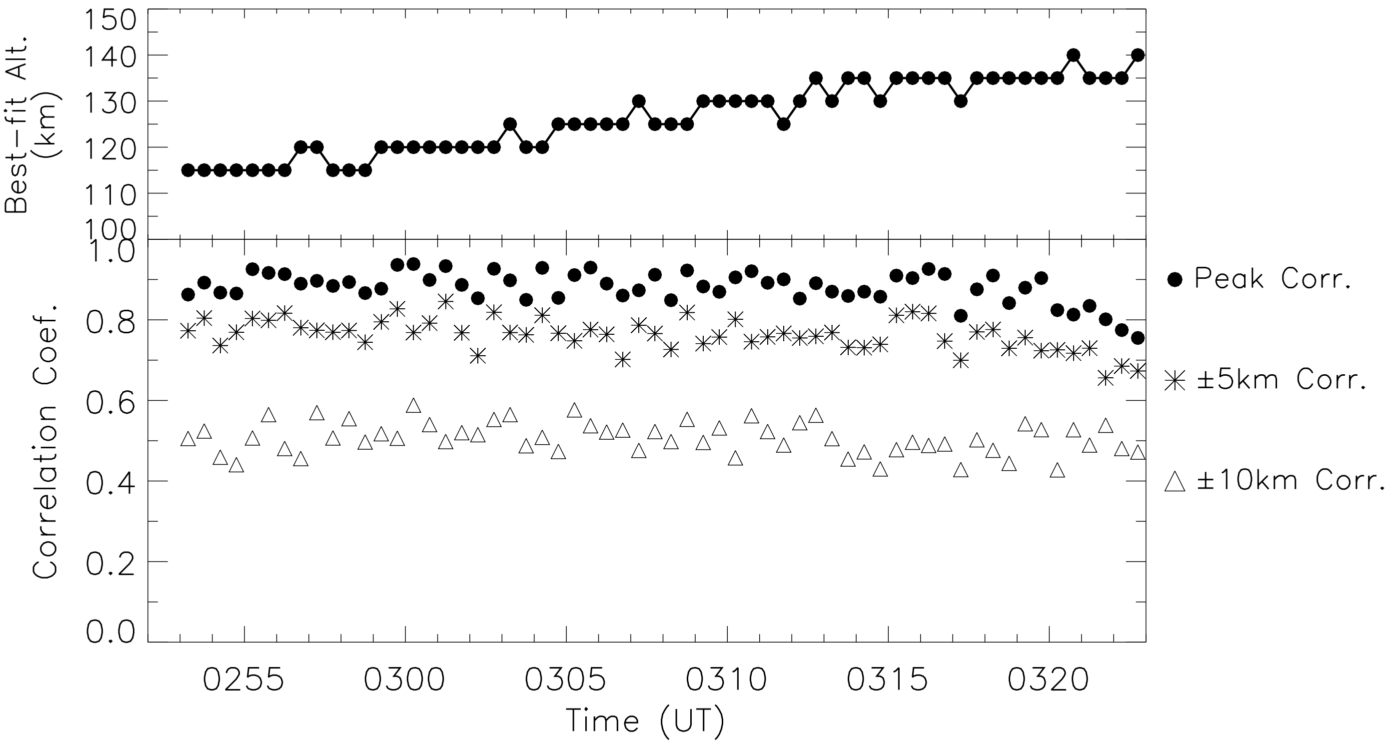

Figure S3. The upper panel shows the best-fit altitude determined at each time epoch. The bottom panel shows the peak correlation at the best-fit altitude, as well as the correlation coefficient averaged for altitudes at 5 km (asterisk) above and below the best-fit altitude, and that averaged for altitudes at 10 km (triangle) above and below the best-fit altitude.