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Auroral spiral structure formation through magnetic reconnection in the auroral acceleration region

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Discrete aurorae, usually displayed as auroral arcs, are universal phenomena in the ionosphere of the Earth and other planets, and are generated by precipitations of electrons from the magnetosphere, ionosphere, and solar wind. Spirals, as frequently observed vortex structures in arcs, have drawn great attention. The formation of auroral spirals is considered to be related to the magnetosphere-ionosphere coupling process during both magnetically active and quiet times. However, how the auroral spirals develop is still an open question. It is suggested that magnetic reconnection occurs in the auroral acceleration region, typically above ~4,000 km altitude in the field-aligned current sheet. Here, using kinetic simulations, we study the role of magnetic reconnection in the formation of auroral spirals, and propose a model to explain the formation of auroral spiral structure.

In our model, an auroral arc develops through precipitations of electrons accelerated during magnetic reconnection in the auroral acceleration region. The arc morphology at low altitudes can be modified by electron-scale magnetic flux ropes, which are generated through secondary oblique tearing modes in the intensified current sheet along one particular branch of the primary reconnection separatrices. The resulting vortex structures agree well with high-resolution observations of auroral spirals. We find that the rotational sense of these spirals is determined by electron kinetic processes and controlled by the guide field direction. Our study further suggests that when the field-aligned length of the auroral acceleration region is shorter than a critical length, these auroral spiral structures will not form.

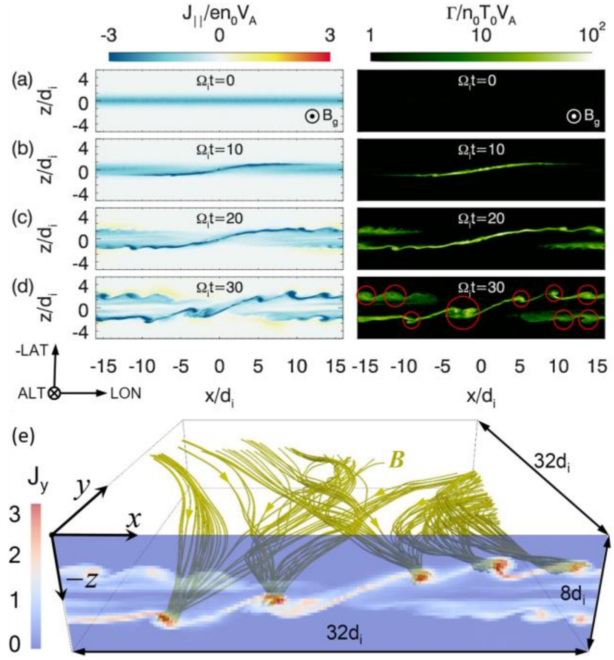

Figure 1 (a-d) show the field-aligned current density $J_{||}$ and electron energy flux Γ on the $y = 1d_i$ plane at $\Omega_i t =$ 0, 10, 20, and 30 respectively. (e) shows the 3-D magnetic field lines of five selected flux ropes and the contours of current density J_y on the y =0 plane.