“Intense Magnetospheric Substorms: What are Known and Unknown”

Zuyin PU
School of Earth and Space Sciences,
Peking University, Beijing, China

Magnetospheric substorms are the fundamental mode of geospace response to the interplanetary magnetic field (IMF) disturbances. Since Akasofu (1964) first interpreted auroral observations through the concept of an auroral substorm, magnetospheric substorms have continuously been one of the main subjects in solar-terrestrial physics. A magnetospheric substorm has three manifestations (Kennel, 1995): the auroral substorm (e.g. aurora breakup and expansion), the polar magnetic substorm (magnetic disturbances in the auroral ionosphere) and the inner magnetotail substorm (including dipolarization and current disruption). Substorm response to IMF disturbances proceeds via two processes: directly driven response and loading-unloading process (Baker et al. 1986; Rostoker et al., 1987). The loading-unloading response consists of three phases: the growth phase, expansion phase and recovery phase (McPherron, 1979). Developments of the auroral, the polar magnetic and the inner magnetotail substorms are in close relation to each other during the loading-unloading phases. Indeed, when the IMF turns southward, more solar wind energy flows to and is stored in the magnetotail. As the accumulation of magnetic energy reaches a critical point, the stored energy is explosively released, and is transmitted to and dissipated in the inner tail and auroral ionosphere. It has become clear that this global energy input-output in the loading-unloading phases proceeds through multiple interactions in the solar wind-magnetosphere-ionosphere (SW-M-I) system; but controversies remain regarding the processes driving the energy loading and unloading.

In the last two decades, in situ multipoint and ground-based measurements and simulations have provided a new insight into the details of the SW-M-I coupling. It is desirable to integrate these new results into the substorm picture, advancing our understanding of this fundamental phenomenon (e.g., Kepko, 2014; Akasofu, 2015). In this lecture we briefly review recent progress in studying energy conversion and transport in the SW-M-I system, concentrating on the physical processes taking place in the loading-unloading courses. We discuss what we have learned and where controversies still exist regarding: (i) How does the solar wind power substorms and where is its energy accumulated in the growth phase? (ii) How is the stored energy released and what parameters control substorm intensity? (iii) How are energy and magnetic flux transported to the inner magnetotail? (iv) How are the inner magnetotail and auroral ionosphere connected at the expansion onset? We aim to show that more investigations are required to fully understand the SW-M-I coupling and energy transport during substorms, the long-time frontier in solar-terrestrial research.