MAGNETOSPHERIC SUBSTORMS AND SOLAR FLARES

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Abstract. Assuming that basic plasma processes associated with magnetospheric substorms and solar flares are similar and thus assuming also that a flare ribbon is produced by the impact of field-aligned current-carrying electrons on the chromosphere, a chain of processes leading to solar flares is considered, including the dynamo process in the photospheric level in the vicinity of bipolar sunspots, the formation of a sheet current in the lower coronal level, the interruption of the sheet current, the subsequent diversion of it to the chromosphere, the development of a potential drop along magnetic field lines, the acceleration of current-carrying electrons and their impact on the chromosphere, producing a pair of flare ribbons.

1. Introduction

Auroral substorms and solar flares (in a narrow sense) are characterized by a sudden flash of highly structured (in space) optical emissions from atoms and molecules of the terrestrial and solar atmospheres, respectively. Figure 1 shows typical photographs of an auroral substorm. The green line (5577 Å), one of the main auroral emissions, arises from oxygen atoms, one of the main constituents in the auroral height of the terrestrial upper atmosphere. The dominant emissions from a solar flare are the Balmer emissions (Hα, Hβ, Hγ . . . ), emitted by atomic hydrogen which is the major constituent of the solar atmosphere.

There are a number of phenomenological similarities between the two phenomena (cf. Akasofu and Chapman, 1972; de Feiter, 1975; Obayashi, 1975). The main optical emissions associated with auroral substorms and solar flares occur spatially in a highly structured manner. In fact, they are often referred to as 'ribbon-like' structures. Flare ribbons appear typically in a pair at the feet of 'arch' of magnetic field lines (cf. Bruzek, 1964; Švestka, 1976; Rust and Bar, 1973). Auroral ribbons in the northern and southern auroral ovals constitute a pair, appearing at the feet of 'arch' of dipolar field lines; auroral displays in the northern and southern ovals are very similar. During an early epoch of auroral substorms and solar flares a sudden brightening 'propagates' or 'extends' rapidly along narrow auroral and flare ribbons. The auroral substorm consists of two phases. During the initial brief (~30 min) expansive phase, auroral ribbons spread rapidly poleward (Figure 1); this active phase is followed by a gradual recovery phase which lasts typically for 2~3 hr. In addition to the above visible emissions, both phenomena are associated with EUV emissions and bremsstrahlung X-ray emissions. Both phenomena are also associated with various types of radio emissions. The light curve has a sharp rise and a slow decay for both phenomena.

Violent plasma motions associated with solar flares have long been known, since they can be observed 'visually' through the Hα filter; note that actually, since the
Fig. 1. A montage photograph of the auroral oval, the belt of auroras around the (invariant) magnetic pole (+mark) over the antarctic region. An intense auroral substorm is in progress, as indicated by a large-scale auroral activity in the night hemisphere (the lower half) of the photograph. The noon meridian is indicated by a line (12) from the pole toward the top of the photograph. The morning meridian (06) and evening meridian (18) are also indicated.

emission arises from atomic hydrogen, their motions are those of partially ionized clouds. Since magnetospheric plasma is not visible, it is only during the last two decades that its motions have become observable by satellite-borne particle detectors.

Magnetic field and electric field variations during auroral activity have long been studied, and the magnetospheric (three-dimensional) current system has been fairly well established. However, for solar flares, magnetic field variations associated with solar flares have been rather controversial. Observed electric field variations in the ionospheric level during auroral substorms are consistent with what one expects from the current system.

Solar flares are associated with the production of suprathermal particles, the so-called solar cosmic rays (solar protons) and relativistic electrons. The production