A SHORT REVIEW OF MAGNETOSPHERIC SUBSTORMS

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1. Introduction

Due to the great number of papers on magnetospheric substorms published in the recent years I will give only a short account of the main progress realized since the publication of Akasofu's (1968) book. The purpose of Figure 1 is to place the substorm phenomena in the general frame of the solar wind magnetosphere interaction. When this interaction increases as a consequence of a southward interplanetary field, energy is stored in the magnetosphere (substorm growth phase). Beyond a certain limit the resultant configuration is unstable and the energy stored is suddenly released producing the substorm expansion phase. A recovery phase ends this explosive part of the substorm; the process repeats as long as the strong interaction is maintained. A reversal of the interplanetary magnetic field northward switches off the strong interaction.

After an account of the difficulties involved in the timing and definition of a 'standard substorm' I will try to give an overall view of the magnetospheric changes involved in the growth phase and the onset of the expansion phase of the substorm and to specify some of the questions which must be answered in order to allow further progress.

2. Definition and Timing of Substorms

Until recently the study of geomagnetic activity was essentially performed from the ground and thus used generally well behaved events. This led to major breakthroughs such as the definition of substorms as the constituent elements of magnetic storms (see references in Akasofu (1968)) and the discovery that a substorm growth phase precedes the expansion phase (McPherron, 1970). In contrast present studies attempt to reach an overall view of the magnetospheric mechanism by primarily using satellite observations of perturbations in space. An attempt to find the ground counterpart of these perturbations leads to several difficulties. First, these ground counterparts include a continuous spectrum of events from the large isolated substorms recorded throughout the whole nightside auroral zone to the 'wiggle' recorded by only one magnetic observatory. They also include events with various combinations of negative and positive bays at two or more magnetic stations. The substorm label has been generously applied to all of these events, and this is the source of some confusion. For instance, the division into three phases which is not always obvious even for a large isolated substorm becomes meaningless for the 'wiggle' and so are the conclusions.

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Fig. 1. Diagram of the two different time sequences of events in the magnetosphere associated with the southward or northward orientations of the solar wind magnetic field. The double lines correspond to purely magnetospheric regimes when the solar wind magnetic field does not change. The bold lines show how the reversals of the vertical component of this solar wind magnetic field allow the magnetosphere to switch randomly from one regime to the other (the vertical positions of the points A and B are arbitrary). Except for the vertical component of the interplanetary magnetic field it is assumed that everything remains constant in the solar wind ($V \sim 400 \text{ km s}^{-1}$, $N \sim 5 \text{ cm}^{-3}$, $B \sim 5 \gamma$, and oriented away from the sun).

drawn from their study. Second, the timing of even a large substorm can lead to controversy. The techniques presently used to determine the onset of the expansion phase (generally taken to be $t=0$, the growth phase time being negative) are the:

(a) onset of a negative bay at an auroral ground station near midnight (Akasofu, 1968);
(b) burst of Pi 2 close to this onset (Camidge and Rostoker, 1970);
(c) sudden brightening and northward motions of the auroral arcs (Akasofu, 1968);
(d) onset of a positive bay at a mid-latitude ground station near midnight (McPherron, 1971b).

Although for a 'standard substorm' all these methods should lead to the same $t=0$ within a few minutes, it appears that for complex events they can lead to completely different timing.

This probably explains some of the contradictory ground satellite correlations published in the recent literature. Another comment could be made about the timing; the emphasis which several years ago was put on ground observations has now shifted to satellite observations. This reflects the fact that we now study magnetospheric substorms as a whole, the auroral (ionospheric) substorm being only one of its consequences. The timing procedure should take account of this new point of view and should accordingly use features related to the magnetosphere (technique (d) above, for instance) and not to the ionosphere alone.