LASCO and EIT Observations of Coronal Mass Ejections

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The LASCO and EIT instruments on the SOHO spacecraft have provided an unprecedented set of observations for studying the physics of coronal mass ejections (CMEs). They provide the ability to view the pre-event corona, the initiation of the CME and its evolution from the surface of the Sun through 30 $R_{\odot}$. An example of the capability of these instruments is provided in a description of a single event (Dere *et al.*, 1997). During the first 2 years of operation of LASCO and EIT on SOHO, a substantial fraction, on the order of 25 to 50%, of the CMEs observed exhibited structure consistent with the ejection of a helical magnetic flux rope. An examples of these has been reported by Chen *et al.* (1997) and Dere *et al.* (1999). These events may be the coronal counterpart of magnetic clouds discussed by Burlaga *et al.*(1981) and Klein and Burlaga (1982). They analyzed observations of magnetic fields behind interplanetary shocks and deduced that the field topology was that of a helical flux rope.

Recently, we have explored a number of the consequences of the helical flux rope description of these types of CMEs. Vourlidas et al. (1999) examined the energetics of CMEs with data from the LASCO coronagraphs on SOHO. The LASCO observations provide fairly direct measurements of the mass, velocity and dimensions of CMEs. Using these basic measurements, we determined the potential and kinetic energies and their evolution for several CMEs that exhibited a flux-rope morphology. Assuming magnetic flux conservation ('frozen-in' fields), we used observations of the magnetic flux in a variety of magnetic clouds near the Earth to determine the magnetic flux and magnetic energy in CMEs near the Sun. Figure 1 shows these quantities for a few representative flux rope CMEs. In general, we find that the potential and kinetic energies increase at the expense of the magnetic energy as the CME moves out, keeping the total energy roughly constant. This demonstrates that flux rope CMEs are magnetically driven. Furthermore, since their total energy is constant, the flux rope parts of the CMEs can be considered to be a closed system above $\sim 2\ R_{\odot}$.

Subramanian et al. (1999) examined images from LASCO to study the relationship of coronal mass ejections (CMEs) to coronal streamers. We wished to test the

Figure 1: On the left, the total (heavy line), potential (dashed line), kinetic (dot-dash line) and magnetic (full line) energies of three CMEs. On the right, their mass (diamonds) and velocity (asterisks).

suggestion of Low (1996) that CMEs arise from flux ropes embedded in streamers near their base. It is expected that the CME eruption would lead to the disruption of the streamer. To date, this is the most extensive observational study of the relation between CMEs and streamers. The data span a period of 2 years near sunspot minimum through a period of increased activity as sunspot numbers increased. We have used LASCO C2 coronagraph data which records Thomson scattered white light from coronal electrons at heights between 1.5 and $6R_s$. Synoptic maps of the coronal streamers have been constructed from C2 observations at a height of $2.5R_s$ at the east and west limbs. We have superposed the corresponding positions of CMEs observed with the C2 coronagraph onto the synoptic maps. We identified the different kinds of signatures CMEs leave on the streamer structure at this height ($2.5R_s$). We find four categories of CMEs with respect to their effect on streamers:

1. CMEs that disrupt the streamer.
2. CMEs that have no effect on the streamer, even though they are related to it.
3. CMEs that create streamer-like structures.
4. CMEs that are latitudinally displaced from the streamer.

Figure 2 summarizes these results. CMEs in categories 3 and 4 are not related to the streamer structure. We therefore conclude that approximately 35% of the observed CMEs bear no relation to the pre-existing streamer, while 46% have no effect on the observed streamer, even though they appear to be related to it.

Previous studies using SMM data (Hundhausen 1993) have made the general statement that CMEs are mostly associated with streamers and that they frequently disrupt it. Our conclusions thus significantly alters the prevalant paradigm about the relationship of CMEs to streamers.

Subramanian and Dere (2000) have examined coronal transients observed on the solar disk in EIT 195 Å images that correspond to coronal mass ejections observed by LASCO during the solar minimum phase of January 1996 through May 1998. The objective of the study is to gain an understanding of the source regions from which the CMEs observed in LASCO images emanate. We compare the CME source regions as discerned from EIT 195 Å images with photospheric magnetograms from the MDI on SOHO and from NSO Kitt Peak, and also with BBSO Hα images. The overall results of our study suggest that a majority of the CME related transients observed in EIT 195 Å images are associated with active regions. We have carried out detailed case studies of 5 especially well observed events. These case studies suggest that active region CMEs are often associated with the emergence of parasitic polarities into fairly rapidly evolving active regions. CMEs associated with prominence eruptions, on the other hand, are typically associated with long lived active regions. Figure 3 summarizes these results.

Figure 2: The relationship of CMEs to streamers

Figure 3: Coronal sources of CMEs

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