The Acceleration and Mass Estimates of Coronal Mass Ejections

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Objectives

To fully understand the magnitude of the forces acting on CMEs as they propagate through the corona.

To fully understand the relationship between CMEs and other forms of solar activity.

*Study CME motions over a wide range of coronal scale heights*
Method

→ Select CMEs which are clearly visible in both Mauna Loa MK3/4 and LASCO images.

→ Measure the height vs. time of CMEs over a wide range of coronal scale heights (1.15-30 solar radii).

→ Generate CME trajectories from Mauna Loa and LASCO observations separately and combined, using a variety of functional fits (polynomial, exponential).

→ Examine CME accelerations, start times, related activity.

→ Determine masses.
A CME visible in both MK4 and LASCO observations on February 18, 2003.

MK4 + LASCO c2 SHOWN IN FIGURE

MK3: 1.15 to 2.45 Rsun  MK4: 1.15 to 2.95 Rsun
LASCO C2: 2 to 6 Rsun  LASCO C3: 4 to 32 Rsun
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CME Acceleration Results

The Acceleration of CMEs

<table>
<thead>
<tr>
<th>CME Source</th>
<th>Distance Range</th>
<th>Average Acceleration</th>
<th>Total Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>MK3/4</td>
<td>1.12 to 2.8 solar radii</td>
<td>591 m/s²</td>
<td>18 measurements</td>
</tr>
<tr>
<td>SMM</td>
<td>1.8 to 5 solar radii</td>
<td>68 m/s²</td>
<td>140 measurements</td>
</tr>
<tr>
<td>LASCO</td>
<td>2 to 32 solar radii</td>
<td>2 m/s²</td>
<td>17 measurements</td>
</tr>
</tbody>
</table>
**Acceleration Results**

CME acceleration greatest in low corona – on average and for ALL events

(Consistent with *St. Cyr et al. 1999, J. Zhang et al. 2001*)

No deceleration detected below 3 solar radii

30% of CMEs observed in LASCO are decelerating
CME Onset Times

Start times generated with LASCO observations alone are systematically later than MK3/4 start times. Acceleration in low corona is unobserved by LASCO. (MacQueen 1985)

Sep 9, 1997 LASCO est. start time: 19:37. MK3 image: 19:34 (Chen et al. 2000)
The Acceleration of CMEs

GOES Integrated Solar Soft-Xray and CME Start Times

17:58 - Start Time from MK3
18:11 - Start Time from LASCO

First MK3 observation of CME at 18:03 at 1.5 solar radii

June 16, 1998    Time [UT]
Getting Accurate Start Times

→ Need low coronal observations to capture early acceleration.

→ Should these be combined with outer coronal observations?
Mass Study

Understand forces acting on CMEs

➜ Estimate CME Excess Mass vs. Height, Time

➜ Determine Source of CME Mass

➜ Estimate CME Potential and Kinetic Energy vs. Height, Time
CME Masses

Skylab  6.2 e+15 grams  1974-1975 (MacQueen 1980)
Solwind  4.1 e+15 grams  1979-1981 (Howard et al. 1985)
SMM  3.3 +/- .1 e+15 g  1980, 1984-1989 (Hundhausen et al. 1994)
LASCO  1.7 e+15 grams  1996-June 2000 (Vourlidas et al. 2002)

SMM Limb  4.5 +/- .5 e+15 grams  1980, 1984-1989 (Burkepile et al. 2004)
February 18, 2003

MK4 K-Coronameter

LASCO C2

LASCO C3
February 13, 2003  CME  Mass Results

Peak Mass in Instrument Field-of-View:

MK4             2.4 e+15 grams
LASCO C2    7.8 e+15 grams
LASCO C3    10.5 e+15 grams

MK4: 1.0 e+15 grams acquired between 1.2 and 2.0Rsun
C2: 0.9 e+15 grams acquired between 2.0 and 4.0Run
C3: 0.8 e+15 grams acquired between 4.0 and 28. Rsun

Source of remaining 7.8 e+15 grams:
Material swept up through outer corona?
Material ejected into CME legs and/or core from low corona?
Conclusions

Acceleration greatest in the low corona.

No deceleration below 3 solar radii (despite gravity).

Inner coronal measurements are needed to obtain accurate start times.

Some CME mass (~15-25% or more?) is swept up from coronal material above the first scale height.

→ Estimated Potential Energies are an upper limit.
Future Work

- Combine CME mass measurements with accelerations to estimate mechanical energies of CMEs.

  Need Velocity Field of CME to get better K.E. estimates

- Utilize most accurate start times to examine CME onset with other forms of solar activity

Future Observations are Important!

STEREO, SDO, MLSO – Coronagraph observations covering a wide range of scale heights are needed to accurately estimate CME accelerations and energies. Low coronal observations are needed to accurately determine CME onset times.