EARLY EVOLUTION OF A CME FROM WHITE LIGHT AND UV OBSERVATIONS

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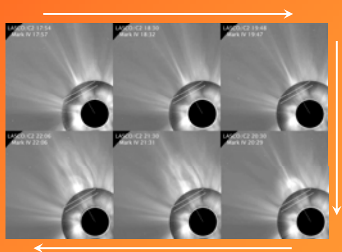
ABSTRACT

At least one third of Coronal Mass Ejections (CMEs) have, in the interplanetary medium, a magnetic flux rope structure, usually referred to as "magnetic cloud". The solar origin of the topology *in situ* flux ropes is debated: according to recent studies only models invoking magnetic reconnection between Active Regions (ARs) and the large scale overlying structures can adequately account for the characteristics of the CME and magnetic cloud fields.

In this work we study the early evolution of a CME which occurred on January 31, 2000, with the aim of inferring the structure of the CME in the early stage of its development and, possibly, to check whether there is any evidence for an interaction between ARs and background structures. Mauna Loa white light and UVCS UV data allowed us to reconstruct the CME configuration: a comparison of the observed structure with that predicted by the Lin & Forbes (2000) CME model shows the two to be quite similar. Densities of the expanding CME bubble and CME core are also given, together with a tentative estimate of the dimension of the CME bubble. Evidence of interaction between the AR where the CME originates and the background structures is also discussed.

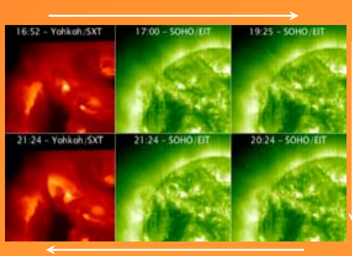
THE CME SCENARIO

On January 31, 2000, LASCO C2 and C3 coronagraphs observed a CME in the NE quadrant at an approximate latitude of 62°, which propagated in the outer corona at a speed of ~ 500 *km/s*. Extrapolating backwards in time, with a constant speed, the CME turned out to be ejected at a time $t \leq$ 18:43 UT.



In this Figure we shows the pre-CME corona (top left panel), from a composite image made up with the data taken by the Mauna Loa Mark IV Coronameter and by the LASCO C2 experi-ment. The successive panels give the coronal configuration during the CME propagation (time runs in the clock-wise way). Mark IV pB images are not avai-lable after about 22:00.

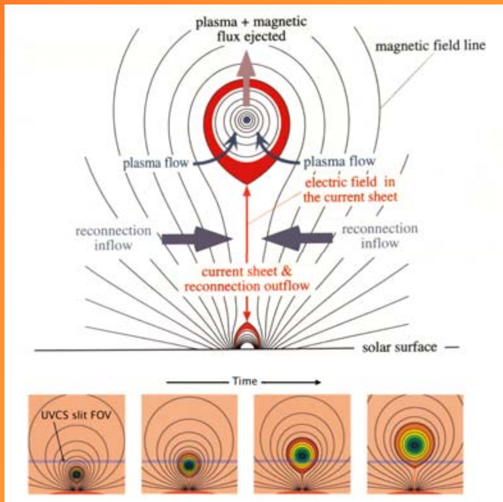
For future reference, the position of the slit of the UVCS spectrometer, set normal to the solar radius at 1.6 and 1.9 R_{sun}, at a latitude of 60°, is also given in the figure.



In order to identify the source re-gion of the CME we analyzed MDI observations of the ARs on the disk. The most prominent AR in the NE quadrant on January 31 is AR 8851 (at a northern latitude of 27° and eastern longitude of 42°), which is rapidly evolving, with a total area and total sun-spot number increa-sing in time.

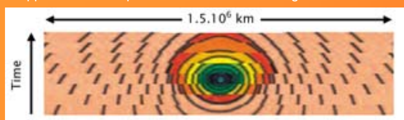
This rapid evolution implies flux emergence and a possibly unstable configuration that makes AR 8851 a likely candidate for the CME ejection. This identification is further supported by EIT and Yohkoh data: Yohkoh SXT data have a gap in between 16:52 and 21:24 UT, hence there is no data coverage at the time of the CME ejection. However, in the first image available after the gap, at 21:24 UT, a prominent cusp-shaped arch is rooted in AR 8851, and an EIT 195Å loop appears to be nested within the SXT loop (see bottom row in this Figure). These newly formed structures provide strong evidence of 8851 being the source of the CME ejection and the site for reconnection of AR fieldlines, torn open by the ejection, and subsequently reforming.

EVOLUTION OF THE CME STRUCTURE: PREDICTIONS VS. OBSERVATIONS



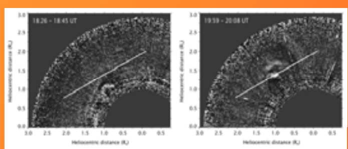
During the CME, the field is strectched outwards, due to the catastrophic loss of equilibrium of the flux rope: a current sheet forms in between the reconnecting loops and the lower tip of the bubble that grows around the flux rope as reconnection progresses outward (top panel in this Figure). The temporal evolution of the bubble is illustrated in the bottom row of the Figure, in a sequence of representative snapshots (from Lin, Raymond & Van Ballegooijen, 2004) that shows the magnetic configuration and the bubble expansion at different times. Each panel covers an area of ~ $2.25 \cdot 10^{12}$ Km^2: simulations show the progressive rise of the CME core and the increasing dimensions of the CME bubble.

As we mentioned, UVCS acquired data at 1.6 and 1.9 solar radii: on the snapshots given above we have drawn a bar, to represent the UVCS slit (width not in scale) and help the reader visualize what UVCS may be expected to observe, if a CME structure happens to be sampled at a fixed altitude during its evolution.

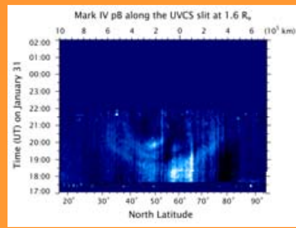


Results from a simulation made cutting through the snapshots panels and letting the rising CME bubble progressively enter a slit set at a constant altitude are shown in the Figure above. This represents the temporal evolution of the topology predicted by the Lin & Forbes (2000) model, as seen by a spectrograph slit.

CME WHITE LIGHT AND UV OBSERVATIONS



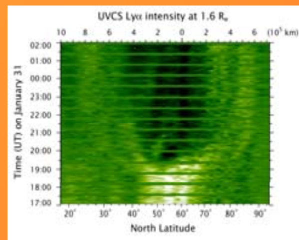
In the left panel we give a sequence of running difference images from the Mauna Loa Mark IV Coronagraph. The posi-tion of the UVCS slit at 1.6 solar radii is also shown. This sequence shows very well the pro-gressive expansion of the CME bubble and the arrival time (about 20:00 UT) of the CME core in the UVCS field of view at 1.6 R_{sun}.



In order to facilitate the com-parison between data taken by different experiments, in this Figure we give the pB bright-ness measured at 1.6 solar radii by the Mark IV experiment over a rectangular area that simu-lates the UVCS slit.

In order to enhance the visibility of faint structures, the pB values given have have been obtained by subtracting from all images the average pB measured, at each latitude, over the whole dataset.

In the panel below we show the Hydrogen Lyman-α λ1216Å intensity (after subtracting the average over the whole dataset) measured by UVCS at 1.6 solar radii, at different times. The similarity with the pB panel is not surprising: pB depends on the electron density and, for a fixed outward velocity and approximately constant electron temperature, the Lyman-α intensity is dictated by the electron density as well. Notice that Lyman-α observations cover a longer time interval than Mark IV data. Both pB and UVCS data show, until ~ 18:30 UT, a bright emission (between a northern latitude of ~ 45° and 65°) which originates from the streamer structure visible in the pre-CME com-posite Mark IV and LASCO image, which disappears after the event. The Lyman-α panel shows that emission appears at positions along the slit which delineate branches, closely resembling the topology pre-dicted by the Lin & Forbes (2000) model. We conclude that Mark IV and UVCS are sequentially imaging the expanding CME bubble: the bright emitting knot imaged around 20:00 UT at a latitude of ~ 50° may represent the CME core, no longer visible at later times because already moved to higher levels.



We may now evaluate the electron density N_e in the bright features described above. To this end we synthesized pre-CME pB values by assuming *a priori* a reference spherically symmetric density profile (in this case the Guhathakurta et al. 1996 profile) and increasing densities with a constant multiplier until the observed pre-CME pB was reproduced. Once the pre-CME densities have been evaluated, we analogously simulated the CME bright features by increasing densities until observed and reconstructed pB were equal.

CME DENSITIES

- **Densities in the knot-CME core are on the order of 1.8 – $4.9 \cdot 10^7$ cm^{-3} (depending on the assumed geometry).**

- **Densities in the CME bubble are on the order of $1.3 \cdot 10^7$ cm^{-3}.**

- **Assuming the whole bubble to be filled with plasma at that density, it turns out that its mass is on the order of $2.0 \cdot 10^{16}$ *g*, while the knot mass is on the order of 1.2 – $3.2 \cdot 10^{14}$ *g*.**

CONCLUSIONS

In this preliminary analysis of pB, WL and UV observations of a CME we have shown that the expanding core – bubble of the Lin & Forbes CME model can be identified since the very early stage of the CME development.

Also, our identification of the CME origin in an AR at a longitude of ~ 45° coupled with the disruption of a streamer imaged by LASCO, is strongly suggestive of an interaction between the AR and the background structures. This interactions seems a necessary feature for the flux rope CME evolution.

ACKNOWLEDGMENTS

This work initiated during a visit of A.B. to the Harvard-Smithsonian Center for Astrophysics whose hospitality and support is gratefully acknowledged.

A.B. and G.P. work has been partially supported by COFIN 2003029124_003.

SOHO is a mission of international cooperation between ESA and NASA.