Deceleration observed in the coronal mass ejection event of July 25, 1999

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RESUMEN

En el presente trabajo presentamos diagramas altura-tiempo de la eyección de masa coronal tipo halo observada en julio 25, 1999 con el Coronógrafo Espectroscópico y de Gran Ángulo (LASCO), a bordo del satélite Observatorio Heliosférico y Solar (SOHO), que puede observar la corona solar de 2 a 32 radios solares. Para obtener estos diagramas se usó una técnica en la cual se dividen las imágenes de LASCO en rebanadas angulares y se coloca lado a lado la misma imagen en diferentes tiempos de observación. Con este método pudimos identificar una pequeña desaceleración de la eyección cerca del polo sur solar.

PALABRAS CLAVE: Eyección de masa coronal, LASCO, SOHO, desaceleración, procesamiento de imágenes, diagramas altura-tiempo.

ABSTRACT

We present height-time diagrams of the halo coronal mass ejection observed on July 25th (1999) from the Large Angle and Spectroscopic Coronagraph (LASCO), on board of the Solar and Heliopheric Observatory (SOHO) able to observe the solar corona from 2 to 32 solar radii. We used a technique in which the LASCO images are divided in angular slices and placed side by side at different observation times, thus producing height-time diagrams. We identify a small deceleration of the July 25th halo CME around the south pole of the sun.

KEY WORDS: Coronal mass ejection, LASCO, SOHO, deceleration, image processing, height-time diagrams.

INTRODUCTION

Coronal mass ejections (CME) are expulsions of solar plasma from the gravitational field of the Sun observed in the corona (Hundhausen *et al*., 1984; Schwenn, 1996; Hundhausen, 1997). These observations are made by coronagraphs that record the photospheric radiation scattered by electrons in the ionized coronal plasma (Bruckner *et al*., 1995). Taking a time sequence of these observations it is possible to identify these coronal outflows. The most recent coronagraphs in operation are from the Large Angle and Spectroscopic Coronagraph (LASCO) experiment on board the Solar and Heliospheric Observatory (SOHO) satellite, a joint project from the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA). This satellite is located at the Lagrangian point L1 on the sun-earth line, distant 240 earth radii from the earth. LASCO provides plane of sky observations of the dynamics of the solar corona by two coronagraphs named C2 and C3, which image the corona from 2 to 6 and 4 to 32 solar radii, respectively.

St. Cyr *et al*. (1999) have analyzed 841 CMEs observed by LASCO from January 1996 to June 1998. For 17% of these events they find some acceleration, but no deceleration was detected for any of the 841 events. However, Sheeley *et al*. (1999) have reported some examples of decelerating CMEs (as well as accelerating ones) using a new image processing technique. The acceleration process is very closely related to the formation of the CME, while the deceleration is probably related to the interaction of the CME with the ambient ahead of it, so it is very important to find out at which distances from the sun these processes take place.

We present a case study of the July 25th (1999) CME in which we observed a small deceleration around the south pole of the sun using a technique of image processing that is able to track the radial moving features seen on the sequence of images. This technique is in some ways similar to the Sheeley *et al*. (1999) one, but with some basic differences that we shall point out.

Determining whether there is deceleration (or acceleration) is also an important parameter for space weather once is can be used in the near future for improving the estimation of the travel time of CMEs to earth.

THE TECHNIQUE

As already mentioned, we have developed an image processing technique very similar to the one presented by Sheeley *et al*. (1999). However some differences do exist between them. Sheeley *et al*. (1999) technique consists in selecting a radial rectangular slice in a given LASCO image, which starts just before the occulter (close to the center) and extends to the extremety of the image. By taking a series of images and extracting the same rectangle (same position) for each of them and placing them side by side, it is possible to have a time history of any moving feature inside this rectangle. Those authors have used running difference images for their analysis, which means that each image was subtracted by its previous one. Also, some radial intensity corrections have been applied in order to make faint features visible at far distances from the sun. The authors recommend a careful read of the Sheeley *et al*. (1999) paper for more details.

The technique used here in this paper consists of dividing each LASCO image in angular sectors, and not rectangular, each sector beginning in the center of the image and with 5 degrees aperture angle. This way, the area covered by each of these slices increase with solar radius. Following that, concentric circles, centered on the image center, were placed in this same figure, each of them 2 pixels of radius bigger then the other. The intersection of the slices with the circles define small areas, that increase size with radial distance from the center. Adding all pixel values inside a single area is equivalent of performing an angular integration. If we take a sequence of images and select only one same slice from each of them, perform the angular integration and place them side by side we have a time history of any moving feature inside this slice. Thus we are able to produce a clear height-time diagram for each angular position and then obtain a height-time scatter plot. This process is illustrated in Figure 1. The angular speed information is lost, but in this work we are interested only in the radial movements of the CME. The radial information is entirely preserved. The angular integration compensates the fading of the structures as they expand, making them visible at long radial distances in the corona. We have used pre-event subtracted images (instead of running difference images), which means that a single reference image taken before the sequence to be analyzed is subtracted from all of the sequence of images.

The July 25th (1999) CME

The July 25th (1999) event was a full halo CME which was visible in all directions around the sun both in the C2 and C3 images. It was first seen at 1454 UT in the C2 and

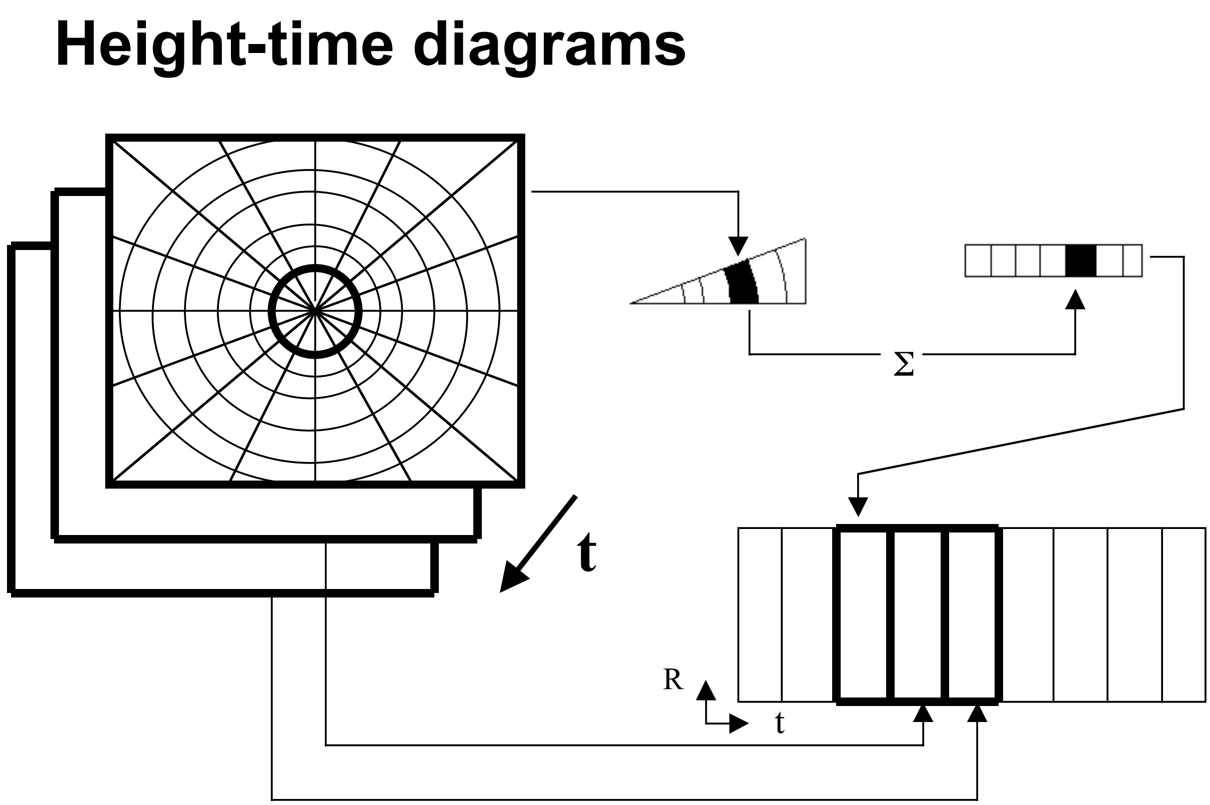

Fig. 1. Illustration of the technique used for image processing. See text for details.

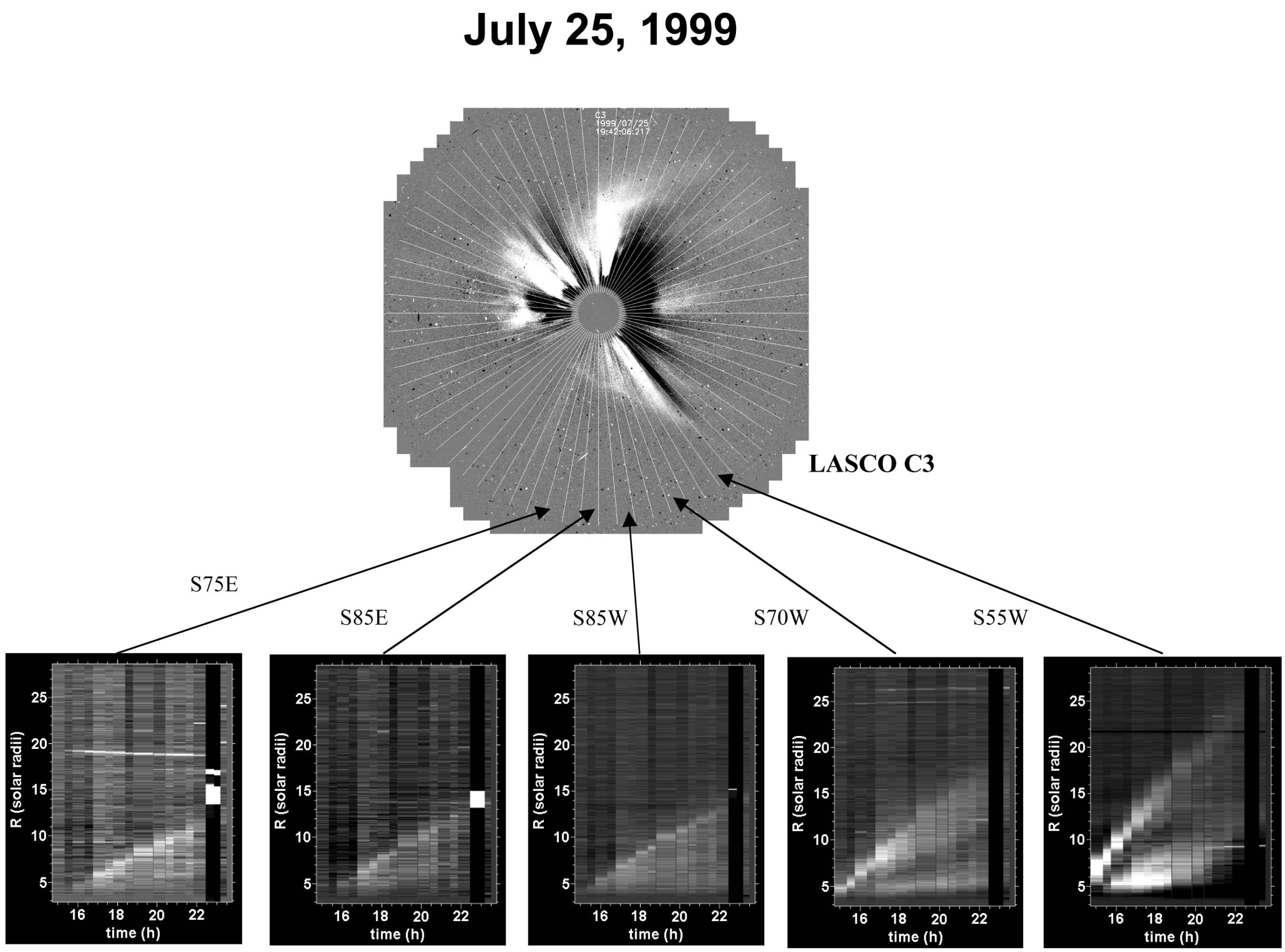

Fig. 2. A LASCO C3 single image taken on July 25th (1999) at 1942 UT showing several positions over the south pole of the sun. The respective height-time diagrams obtained from our technique are places in the bottom for the positions S75E, S85E, S85W, S70W and S55W.

lasted beyond 2200 UT in the C3 field of view. We applied our technique for the positions S75E, S85E, S85W, S70W and S55W, around the south pole of the sun. Figure 2 shows a LASCO C3 single image taken on July 25th (1999) at 1942 UT. For all the positions mentioned above we applied our technique and the resulting height-time diagrams are shown in the bottom of Figure 2. In each of these height-time diagrams the horizontal axis is the time (hours) and the vertical axis is the radial distance (solar radii) from the sun.

Using the obtained height-time diagrams of Figure 2 we could easily obtain their height-time scatter plots which are shown in Figure 3. A second order polynomial fit was added to each of the scatter plots, from which it is possible to observe a small deceleration in the chosen directions.

Table 1 shows the initial and final speeds and the decelerations for each of the directions shown in Figures 2 and 3. These results are in good accordance with another study made by Sheeley *et al*. (2000) using the other technique.

SUMMARY AND DISCUSSION

Height-time diagrams for the July 25th (1999) halo coronal mass ejection were obtained using a technique of image processing that helped to track the radial movements of this CME. The technique, which performs an angular integration in the LASCO images, permitted the visualization of faint structures far in the corona.

The height/time diagrams obtained after processing the images revealed a small downward curvature indicating deceleration over the south pole. Height-time scatter plots obtained from the diagrams were very well fitted by a second order polynomial curve confirming the small deceleration in these directions. The solar disk source related to this CME

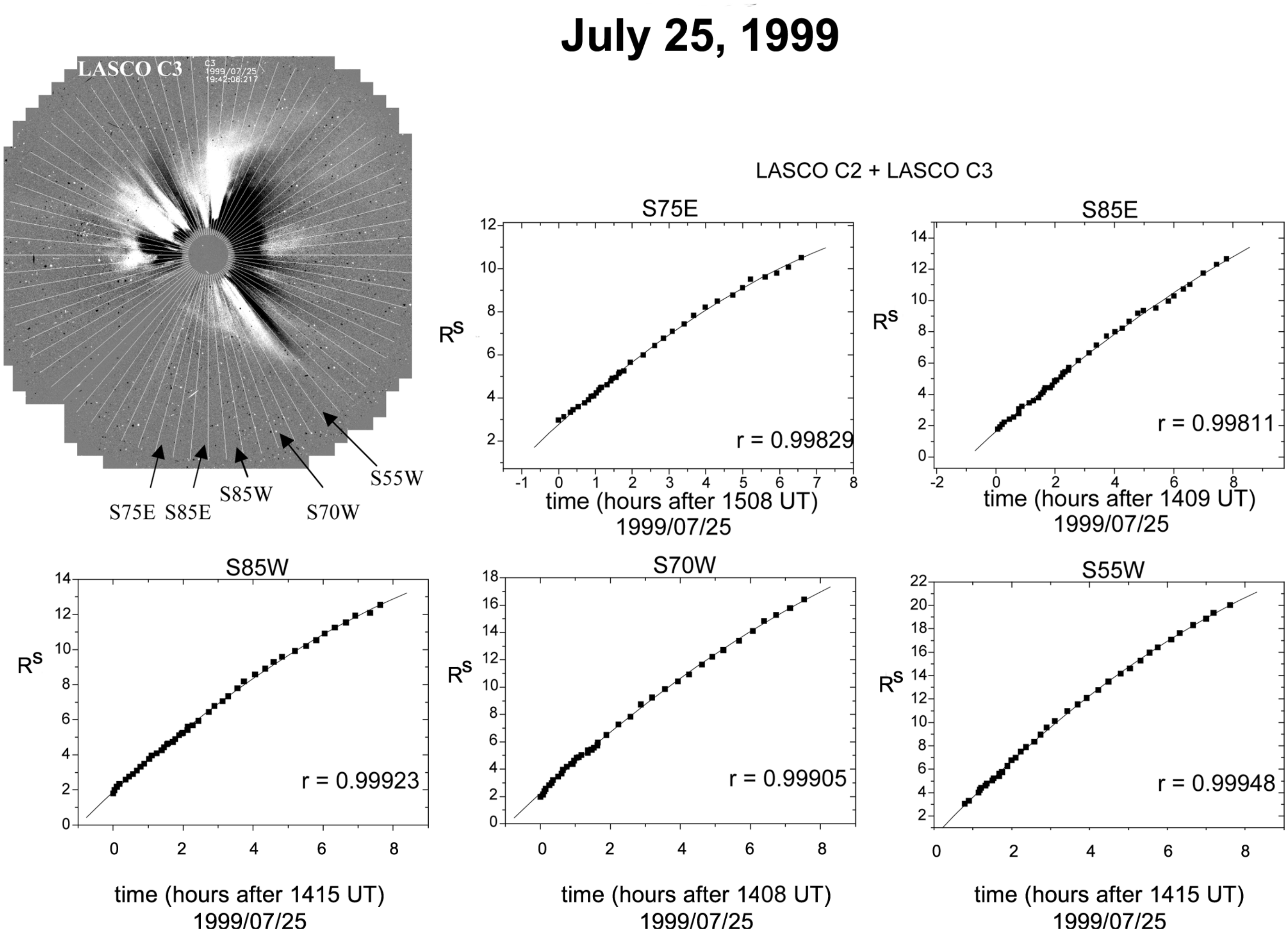

Fig. 3. Height-time scatter plots obtained from the bottom diagrams of Figure 1 for the positions S75E, S85E, S85W, S70W and S55W. A second order polynomial fit was added to each of the diagrams.

Table 1

Initial and final speeds and decelerations of the positions shown in Figures 2 and 3

	V_0 (km/s)	V_f (km/s)	a (m/s^2)
S75E	310.49	145.59	-6.48
S85E	336.25	209.76	-4.24
S85W	368.18	175.10	-6.54
S70W	466.31	261.03	-7.06
S55W	649.87	325.69	-12.3

was very close to the west limb. Nevertheless it was a full halo CME, ejecting material all around the disk, which indicates that it had a velocity component in the sun-earth direction, with the highest front speed probably in some direction inclined toward the west limb. This means that the real radial distances from the sun in the directions chosen in our analysis should have been bigger than the projections seen in the plane of sky, with the possibility of exceeding 30 solar radii. For purely limb events, no deceleration has ever been reported in the literature until now, only for halo CMEs (Sheeley *et al.*, 1999), so this result obtained here support the hypothesis that deceleration occurs at relatively far distances (> 30 solar radii), thus being observed only in halos. Projection effects can be the responsible for the differences in the deceleration values at different positions chosen in our study.

Concerning the technique, it has revealed itself very appropriated to identify whether there is acceleration or deceleration on CMEs.

As pointed out in the introduction, acceleration and deceleration are closely related to the CME initiation mechanism and to its interaction with the surrounding ambient. Also, this kind of measurements can be of extreme importance for the space weather studies, since they can be used to predict the travel time of the CMEs to earth.

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