The early January coronal mass ejection and the estimate of its arrival to Venus

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Abstract (Font: Arial Bold, 9)

On January 8th, 2007, at 14:54UT, a coronal mass ejection (CME) was observed by LASCO C2, onboard SOHO. Latter on the same day, LASCO C3 also observed this CME, which continued moving outward during most of January 9th. SOHO/EIT did not detect any activity on the solar disk during this period, suggesting that the CME was ejected behind the East limb, towards planet Venus. Thus, we expect the CME to reach Venus some few days after its launch. STEREO/SECCHI COR1 and COR2, A & B, coronagraphs also observed the same CME event. Because STEREO was in the early beginning of its mission, both spacecrafts A and B were near the Earth, and it was possible to combine observations from their instruments and SOHO/LASCO. We estimate the travel time of the Jan. 8th-9th (2007) CME from the Sun to Venus using 3 approaches. In the near-future, our estimates should be confirmed when data from Venus Express mission is available.

Introduction

Coronal mass ejections (CMEs) are eruptive events observed in the solar corona, in which huge quantities of mass and magnetic filed are released to the interplanetary space (Hundhausen, 1997). CMEs are one of the main causes of magnetic storms on earth (Gosling, 1993) and might as well hit other planets, like Venus (Luhmann et al., 2008). On January 8th, 2007, at 14:54UT, a coronal mass ejection (CME) was observed by the Large Angle and Spectrometric Coronagraph (Brueckner et al., 1995) – LASCO C2, aboard the Solar and Heliospheric Observatory (SOHO). The event was observed in the East limb, position angle (PA) 65 degrees. Latter on the same day, LASCO C3 also observed this CME, which continued moving outward during most of January 9th. SOHO's Extreme Ultraviolet Imaging Telescope - EIT did not detect any activity on the solar disk during this period, suggesting that the CME was ejected behind the East limb. The Sun Earth Connection Coronal and Heliospheric Investigation (Howard et al., 2002) - SECCHI COR1 and COR2, A and B, coronagraphs, aboard the Solar Terrestrial Relations Observatory (STEREO) also observed the same CME event. Because STEREO was in the early beginning of its mission, both spacecrafts A and B were near the Earth, and it was possible to combine observations from its instruments and SOHO/LASCO.

Method

Using a high precision measurement technique which consists of taking a specific angular sectors of coronagraph images in distinct times (Dal Lago et al., 2003), it is possible to measure the CME velocity in the plane of sky. Figure C1 shows, on the upper right position, the CME observed by STEREO/SECCHI COR1 B at 14:41UT and the same image post processed using 5 degrees integration slices. Time variation of the PA65 slice, just in the center radial direction of the CME, is shown in the lower left in a height-time diagram. It is possible to identify the radial motion of the CME leading edge and its trailing bright prominence. In the middle right, a SOHO/LASCO C3 snapshot on Jan. 9th, at 02:42UT is shown, together with the same 5 degrees integration sliced post processed image. In the lower right it is shown the evolution of the CME up to ~20 solar radii. On the upper left, a combination of measurements obtained from height-time diagrams using the slice integration technique for STEREO/SECCHI COR1 A, COR1 B, COR2 A, COR2 B, SOHO/LASCO C2 and C3 is shown. A clear acceleration is observed in between 18:00UT and 22:00UT, when the CME plane of sky speed jumps from 70 km/s to 284 km/s.

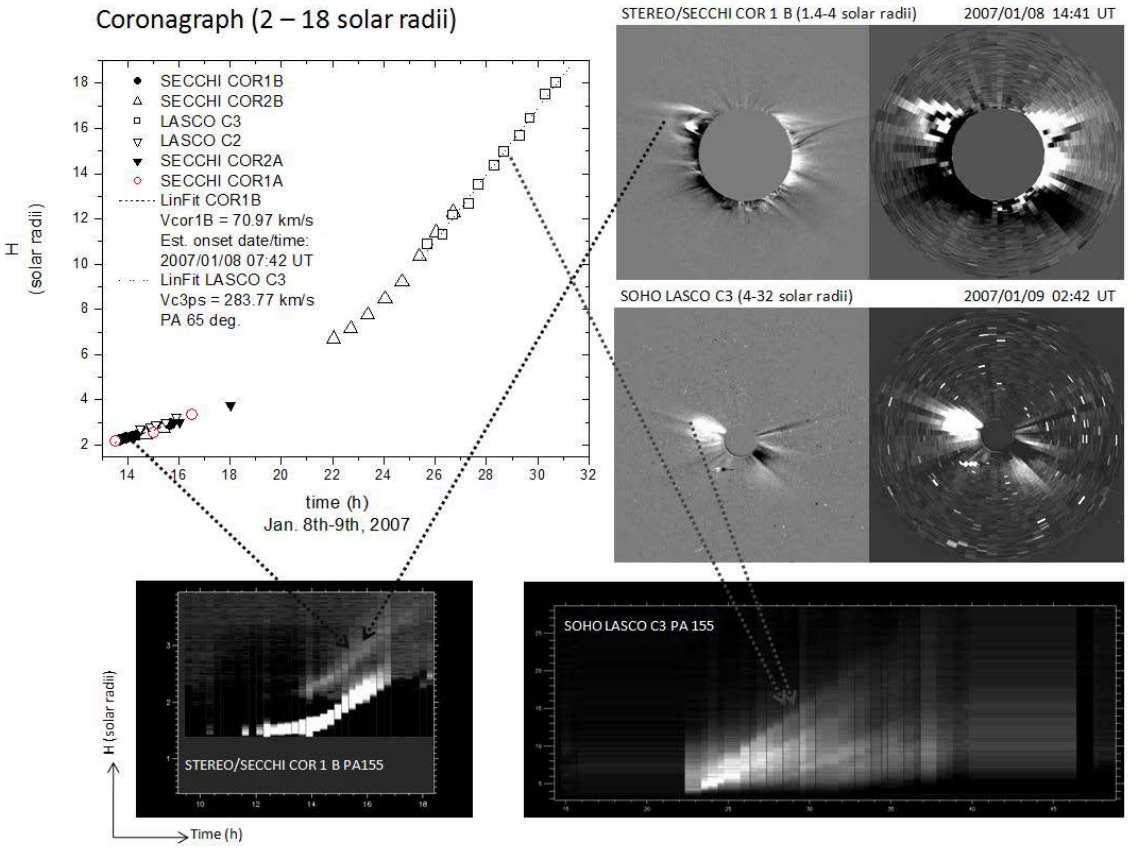

Figure 1. Upper right: CME observed by STEREO/SECCHI COR1 B at 14:41UT and the same image post processed using 5 degrees integration slices. Lower left: time variation of the PA65 slice, just in the center radial direction of the CME, in a height-time diagram. Both leading edge and bright prominence dynamics are distinguishable. Middle right: SOHO/LASCO C3 snapshot at Jan. 9th, at 02:42UT together with the same 5 degrees integration sliced post processed image. Lower right: evolution of the CME up to ~20 solar radii. Upper left: combination of measurements obtained from height-time diagrams using the slice integration technique for STEREO/SECCHI COR1 A, COR1 B, COR2 A, COR2 B, SOHO/LASCO C2 and C3.

Few days latter, on January 12th, an active region (AR) started to appear on the East solar limb. This was the NOAA AR10938, and it was probably correlated to the CME when it was lifted off few days earlier from behind the East limb. By the time the CME was ejected, AR10938 was at disk center if observed from Venus. Thus, we expect the CME to reach Venus some few days after its launch.

In order to estimate the travel time of the Jan. 8th-9th (2007) CME from the Sun to Venus, we shall consider 3 approaches: (1) comparison with similar past events; (2) CME travel time model adapted to 0.72AU; and (3) constant final LASCO C3 velocity assumption.

Sheeley et al. (1985) studied CMEs and corresponding ICMEs using quadrature observation from SOLWIND coronagraph (Sheeley et al.,1980) and Helios 1 plasma analyzer (Rosenbauer et al., 1977) from 1979 to 1982. From 56 events, 5 occurred when Helios 1 was at a heliocentric distance of 0.72 + 0.05 AU. These events are shown in Table 1.

Table 1. Quadrature observation of CMEs and corresponding ICMEs using SOLWIND coronagraph and Helios 1 plasma analyzer at heliocentric distance of 0.72+ 0.05 AU, from 1979 to 1982 (adapted from Sheeley et al., 1985).

Year	CME date	CME time	CME speed (km/s)	ICME date	ICME time	Helios 1 helioc. Dist. (AU)	Travel time from the Sun (h)
1979	Oct. 10	07:13	170	Oct. 13	02:00	0.72	67
1981	May 8	23:35	1000	May 10	03:20	0.67	27
1981	Jul. 22	20:49	800	Jul. 24	15:28	0.74	43
1981	Nov. 15	00:15	550	Nov. 16	15:19	0.67	39
1982	Nov. 22	20:30	620	Nov. 24	00:01	0.74	27.5

CME speeds in Table 1 range from 170 to 1000 km/s. In order to compare these events with the January 8th-9th (2007) CME, it must be considered the fact that SOLWIND coronagraph field of view was 2.6-10 solar radii (Sheeley et al., 1980). Figure 2 is similar to the upper left diagram of Figure 1, but for the same range of SOLWIND coronagraph (2.6-10 Ro). STEREO/SECCHI COR 2A, COR 2B and SOHO/LASCO C2 data points are displayed in the figure. A linear fit to the data points is also shown in Figure 2, indicating a speed of 120 km/s. From this CME speed, the January 8th-9th (2007) CME is similar to the October 10th (1979) CME shown in Table 1. From this similarity, a 67 hours travel time from Sun to 0.72 AU is estimated.

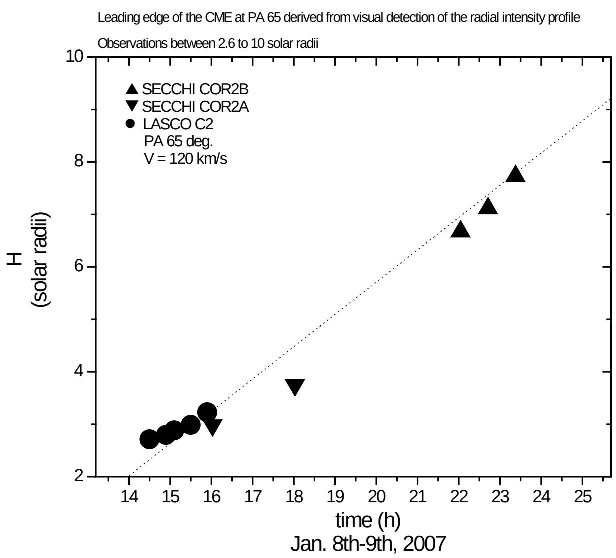

Figure 2. Similar to the upper left diagram of Figure 1, but for the same range of SOLWIND coronagraph (2.6-10 Ro). STEREO/SECCHI COR 2A, COR 2B and SOHO/LASCO C2 data points are displayed. A linear fit to the data points is also shown, indicating a speed of 120 km/s.

Using a set of SOHO/LASCO C3 and Advanced Composition Explorer (ACE) 1AU observations in the period from 1997 to 2001, Schwenn et al. (2005) derived an empirical model to predict CME travel time from the Sun to 1AU. This model requires a quantity called “CME expansion speed”, which is the CME growth rate perpendicular to the fastest CME radial plane of sky speed. CME expansion speed can be measured for halos, partial halos or limb CMEs, and that is precisely the advantage of this methodology. Using SOHO/LASCO C3 data, expansion speed for the January 8th-9th (2007) CME was measured to be Vexp= 260 km/s. Derivation of CME travel time to 1AU is as follow:

t_{1AU} = 203 – 20.77*ln(Vexp); (Schwenn et al., 2005) (1)

t_{1AU} (Vexp=260km/s) = 87 hours (2)

Since the dynamics of CMEs throughout their transit in the interplanetary medium is not known (acceleration, deceleration, etc.), a simple assumption to estimate the CME travel time to 0.72AU is as follow:

$T_{0.72AU}$ = 0.72* t1AU (3)

Hence,

$T_{0.72AU}$ = 63 hours (4)

Another possible assumption to estimate the travel time from the Sun to Venus is simply to assume that the CME propagated at a constant final LASCO C3 speed. In this case, the January 8th-9th (2007) CME would have traveled at a constant 284 km/s velocity from the Sun to Venus in 105 hours. It is believed that such slow CMEs are probably accelerated by the solar wind (e.g. Gopalswamy et al., 2000). For example, the famous January 6th (1997) CME was very similar to the January 8th-9th (2007) one, with a final LASCO C3 speed of 224km/s (from SOHO LASCO CME catalog in http://cdaw.gsfc.nasa.gov/CME_list/). The 1997 event traveled from the Sun to 1AU (earth) in 81 hours. Thus, the estimate using constant final LASCO C3 velocity seams unrealistic for this event. Table 2 sumarizes the estimates of travel time to 0.72 AU for the January 8th-9th (2007) CME for the distinct methods.

Table 2. Estimates of travel time to 0.72 AU for the January 8th-9th (2007) CME.

Assumption	Travel time to 0.72 AU (hours)	Estimated arrival date/time in Venus
comparison with similar past events (Sheeley et al., 1985)	67	Jan. 11th (2007), 09:54 UT
CME travel time model (Schwenn et al., 2005) adapted to 0.72AU	63	Jan. 11th (2007), 05:54 UT
constant final LASCO C3 velocity	105	Jan. 12th (2007), 23:54 UT

Conclusions

Our estimates of the time of arrival of the early January coronal mass ejection to Venus indicate that it should have occured sometime in the mourning of Jan. 11th 2009. This conclusion is based on the agreement of two out of three methods. When Venus Express magnetic field data will be available for this period, we will be able to confirm our estimate. The importance of this study is to check CME travel time models taking the advantage of the quadrature observations using near-earth coronagraphs and plane of sky in situ observations (at Venus). Such models will be of extreme importance to Space Weather forecast on earth.

Acknowledgments

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