CHAPTER 3

TWISTED ERUPTIVE PROMINENCE OF 7 DEC 2001 ASSOCIATED WITH CMEs[@]

@ Based on : Pooja et al., 2013, Twisted Eruptive Prominence of 7 Dec 2001 Associated With CMEs, Acta Ciencia

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3.1 Introduction

A Solar prominence is an object in the chromospheres which is comparatively denser (density ~10^{-11} gcm^{-3}) and cooler (temperature~7000K) than its surroundings. It has been known for some time (Hundhausen, 1993) that coronal mass ejections (CMEs) are often associated with prominence eruptions because we know now that the inner core of CMEs is made up of prominence material (see, e.g., et House al. 1981). Here, some authors have treated the prominence eruption as a secondary process of the CME phenomenon, since the prominence itself may not have enough energy to drive a CME (Hundhausen, 1999; Smith, Hildner, and Quin, 1992).

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Subsequently, the relationship between prominence eruption and CMEs has been investigated by many authors (Schmieder et al. 2002; Gopalswamy et al. 2003; Lin 2004, Syed Salman Ali 2006, and the references therein) but the overall association between prominence eruption and CMEs is not well understood so far. Therefore, in the present study we have made an attempt to explore the association between prominence eruption and CMEs of 7 Dec 2001.

3.2 Observation

To carry out the present study, we have used Nobeyama Radio heliograph data. NORH observes the Sun at 17 & 34 GHz between 22:30 & 6:30 UT and provides the high- quality data for up to 8 hrs. per day with little interruption due to weather conditions. The microwave images have a spatial resolution of ~ 15" and 8" at 17 and 34 GHz, respectively. We have used only 17 GHz images archived at the Nobeyama Radio Observatory for the present study. Further details are available in Gopalswamy 2003.

The associated CMEs have been observed by the Large angle and spectrometric coronagraph on-board SOHO (soho/lasco; Brueckner et al, 1995) in the field of view of C2 and C3 instruments. The field of view of the C2 and C3 coronagraph extend from $2R_{®}$ and $4R_{®}$ to $30R_{®}$ respectively.

3.3 Morphology and kinematics

3.3.1 Chronology of events

We have summarized the Chronology of the events in below mention Table and illustrated the most important developments in figure 3.1, which include selected NORH of prominence eruption and white light LASCO C2 andC3 images.

01:15:02 UT	Prominence activation and slow rise (≈2km/sec)
01:35:02 UT	Activation strongly rises (≈ 43km/sec)
02:05:02 UT	Wave like structure simplified
02:15:02 UT	Acceleration minimum (≈ 6.94×10^{-6} m/sec^{-2})
02:25:02 UT	Acceleration dropped to zero (at ≈ 3, 33,928km.)
02:35:02 UT	Velocity is maximum (≈ 87.5km/sec) and "Knots" of mass separated and moved away the sun
02:45:02 UT	strongly de-acceleration at ≈ (□ 155.3km/sec), PEs gap simplified
02:55:02 UT	Acceleration maximum (≈ 2.11×10^{-4}m/sec^{-2}), semicircle simplified
03:05 UT	CME appeared in the LASCO C2 field of view with cavity
03:54UT	Core simplified

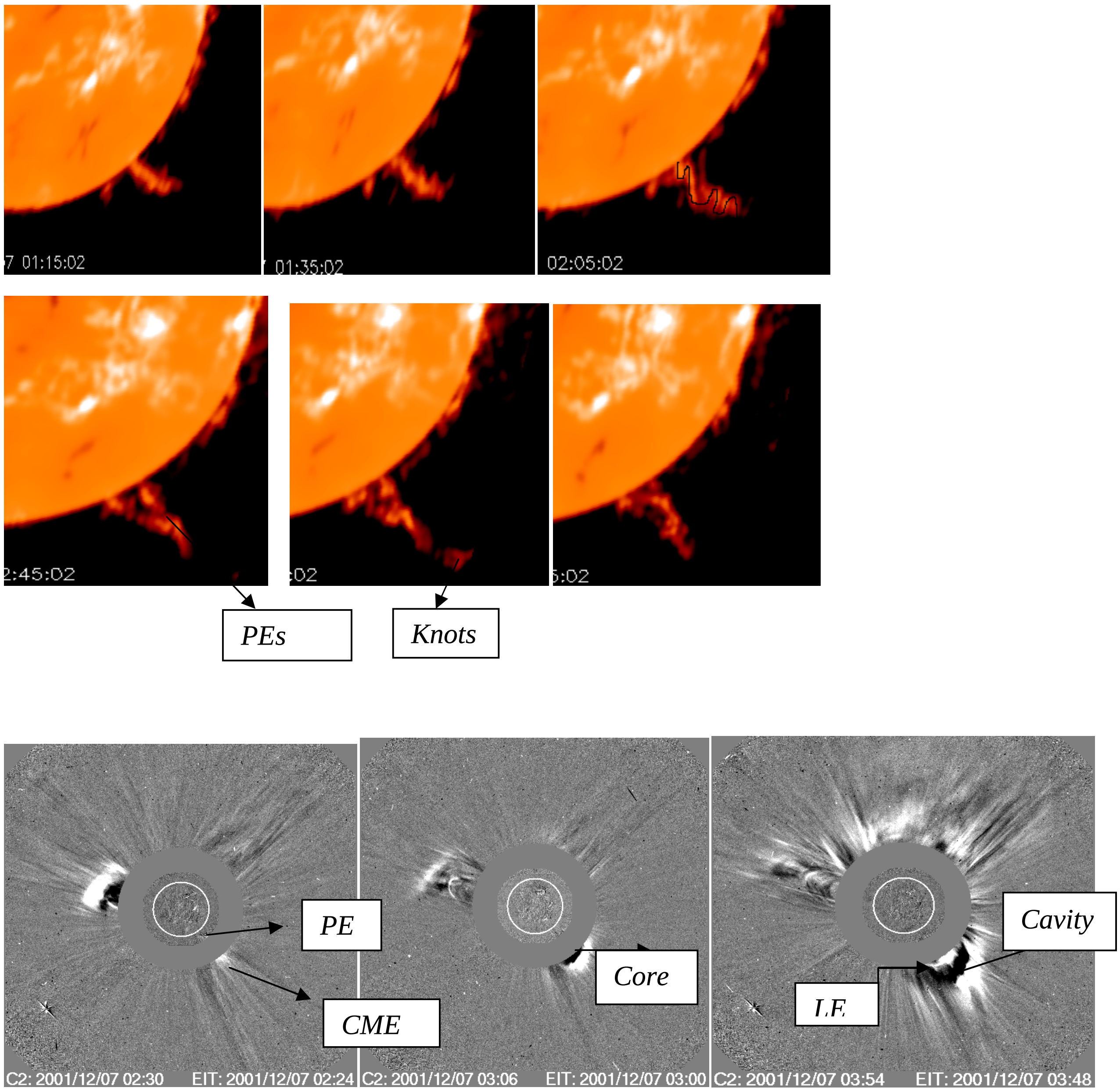


Figure 3.1: Evolution of the NORH prominence (upper two rows), The 17 GHz Nobeyama Radio heliograph images at 02:05:02 UT, Dec 7, 2001, showing the extended helical wave-like nature and at 02:55:02

UT, showing the semicircle nature and LASCO C2 images (bottom row). North is up; west is right.

3.4 Spatial and Temporal Relationship between CMEs and Prominence Event

The prominence eruption as well as the eruption of associated CMEs occurred on 7 Dec 2001.The spatial correlation between prominence and CMEs can be understood with the help of NORH images, EIT 195Å difference image and LASCO observations of CMEs (Fig 3.1).Comparing the position of prominence eruption with the position angle of CMEs suggests that these events are spatially correlated. Moreover, the composed LASCO/C2-EIT image (bottom left panel of figure 3.1) shows the EIT erupting PEs below the advancing CMEs, this confirming that these events are spatially correlated.

To study the temporal relationship between these events the height-time profiles of these events are plotted and compared in Fig 3.2.Also, in Fig 3.2 (left) the height-time profiles of the prominence and the leading edge of the first CME are plotted. At 02:35 UT the leading edge of the prominence was at 1.60 R_{sun} whereas the extrapolated height of the first CME at 02:35 UT was at1.0R_{sun}.So, the plot reveals strong temporal association between these two phenomena.

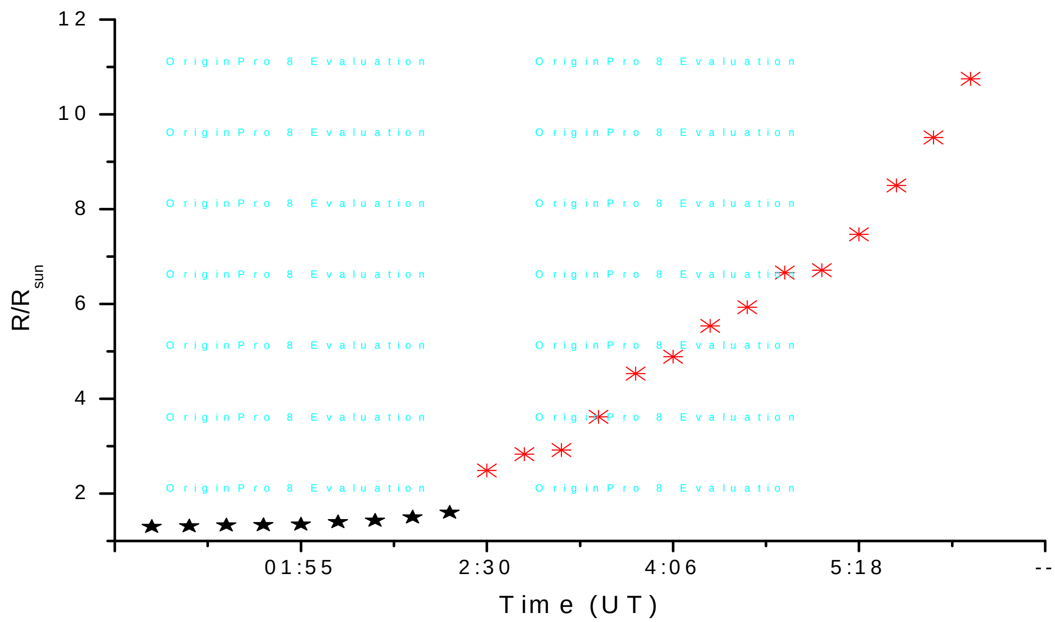


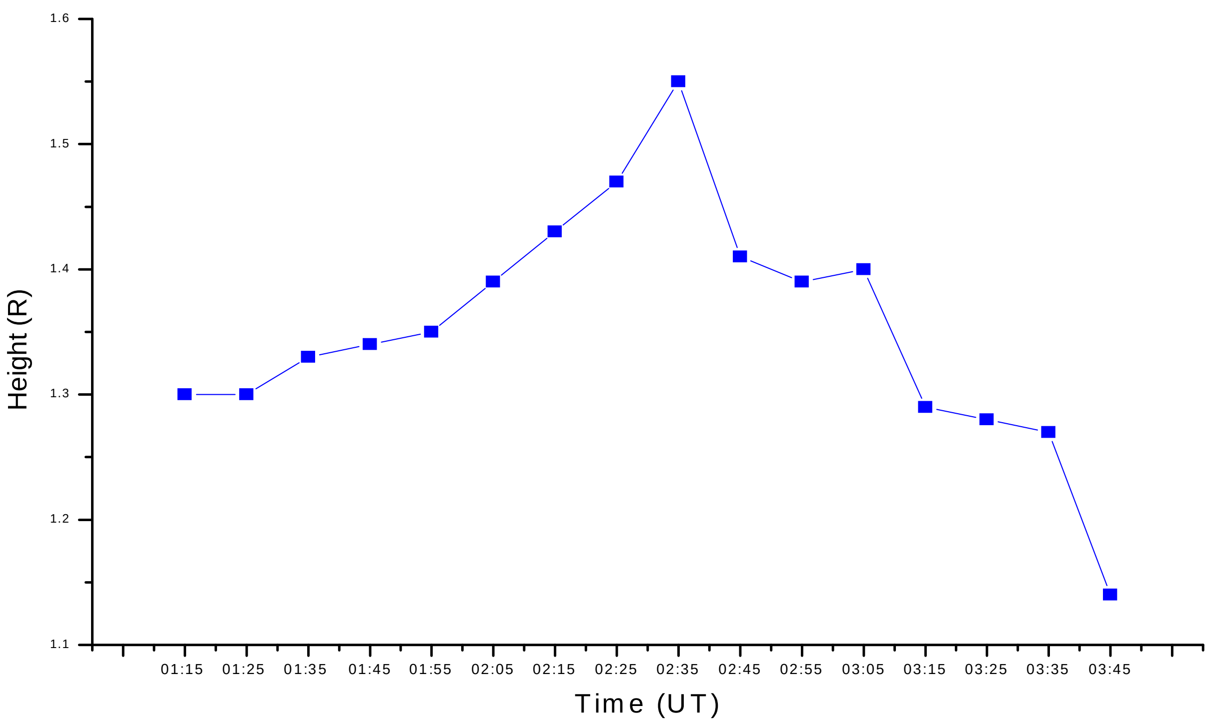
Figure 3.2: The height-time profiles of the CMEs (red star), the prominence (black star).

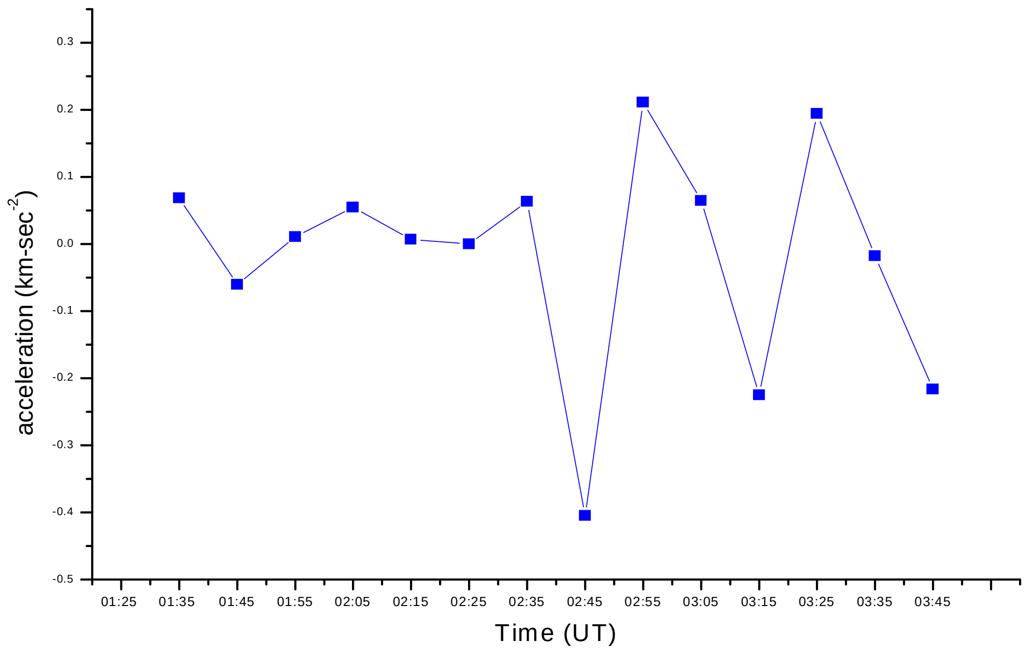
3.5 Prominence Kinematics

The smoothed height – time profile (for details of the procedure see the Appendix) of the leading edge of the prominence, along with the velocity and acceleration profiles, are presented in figure 3.3. The plots reveal that destabilization of the prominence started before 01:15:02 UT, since at this time the ascending motion was already characterized by the velocity of 2km/sec, which was observed for about 10 min. Thereafter, the prominence velocity started to rise and slow with an average acceleration (□$1.78\times10^{-5}ms^{-2}$).

The acceleration maximum of 2.11×10^{-4}m/sec^{-2} was attained at around 02:55:02 UT, at a height of 276071.43 km (1.39 □). At this stage the prominence velocity was -28.57km/sec.

We have found that the prominence associated CMEs do not show a linear rising motion. It initially rises with an average speed of 36km/sec, then it slow down and it seems to move in the opposite direction, i.e., towards the solar surface. Then the rising motion starts again with 10km/sec and reached at the onset of the eruption phase. We can conclude that the prominence motion is characterized by an initial smooth oscillating behaviour and a successive abrupt rising.





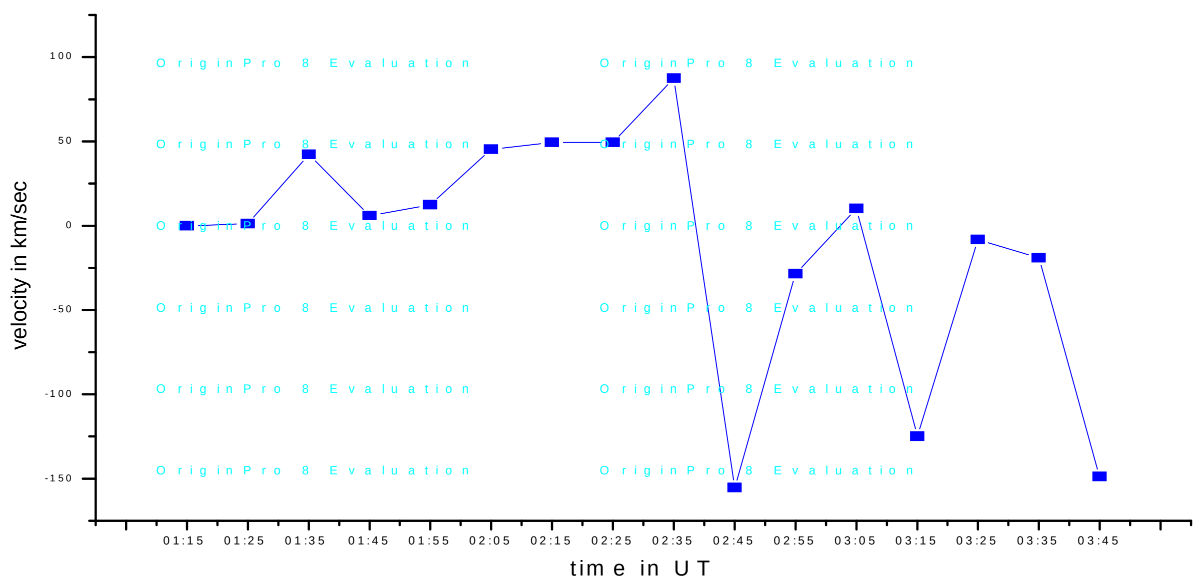
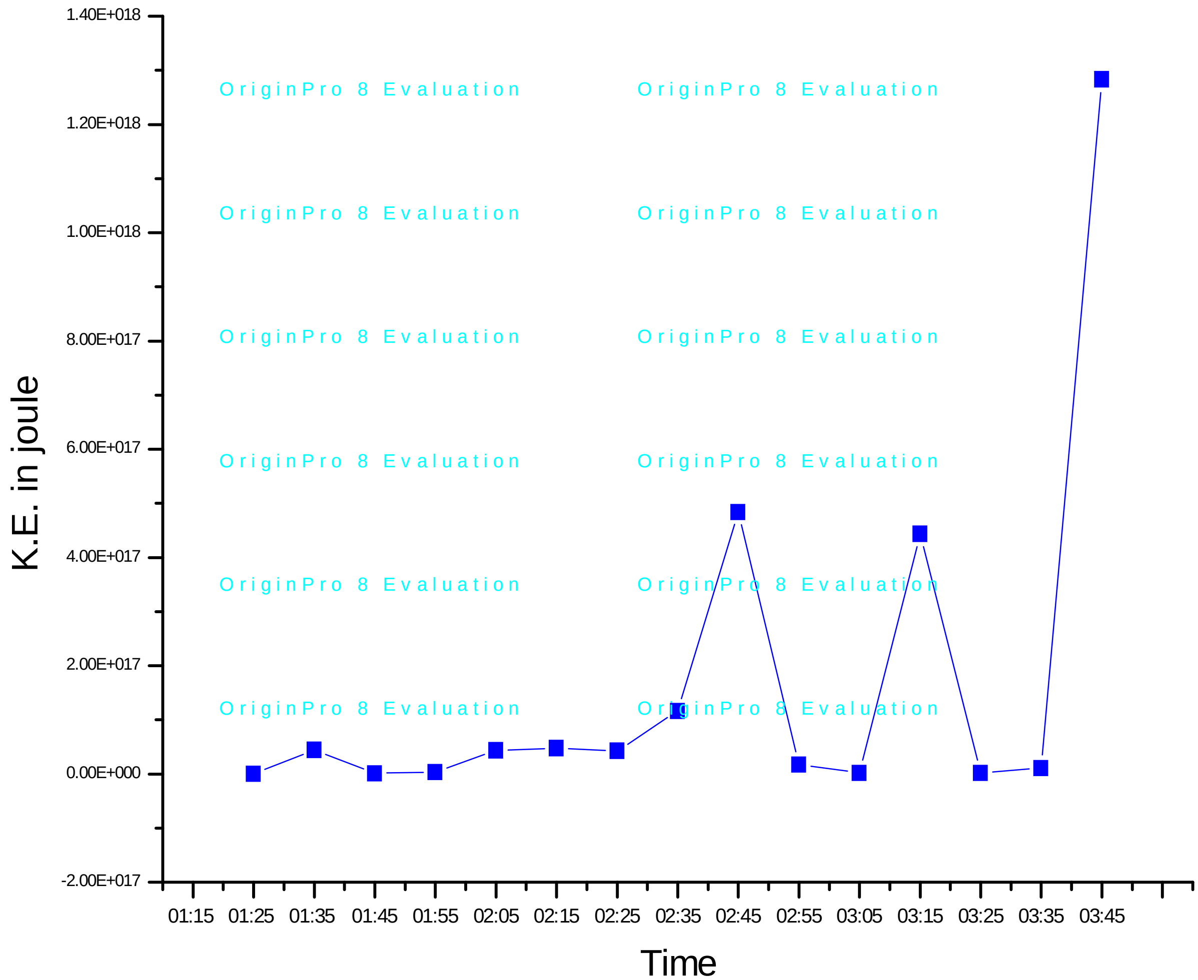


Fig-3.3: The smoothed height-time profile and NORH data (dots), Velocity profile, and acceleration profile of the prominence.



1.40E+018
1.20E+018
1.00E+018
8.00E+017
6.00E+017
4.00E+017
2.00E+017
0.00E+000
-2.00E+017
K.E. in joule
01:15
01:25
01:35
01:45
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02:05
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Time
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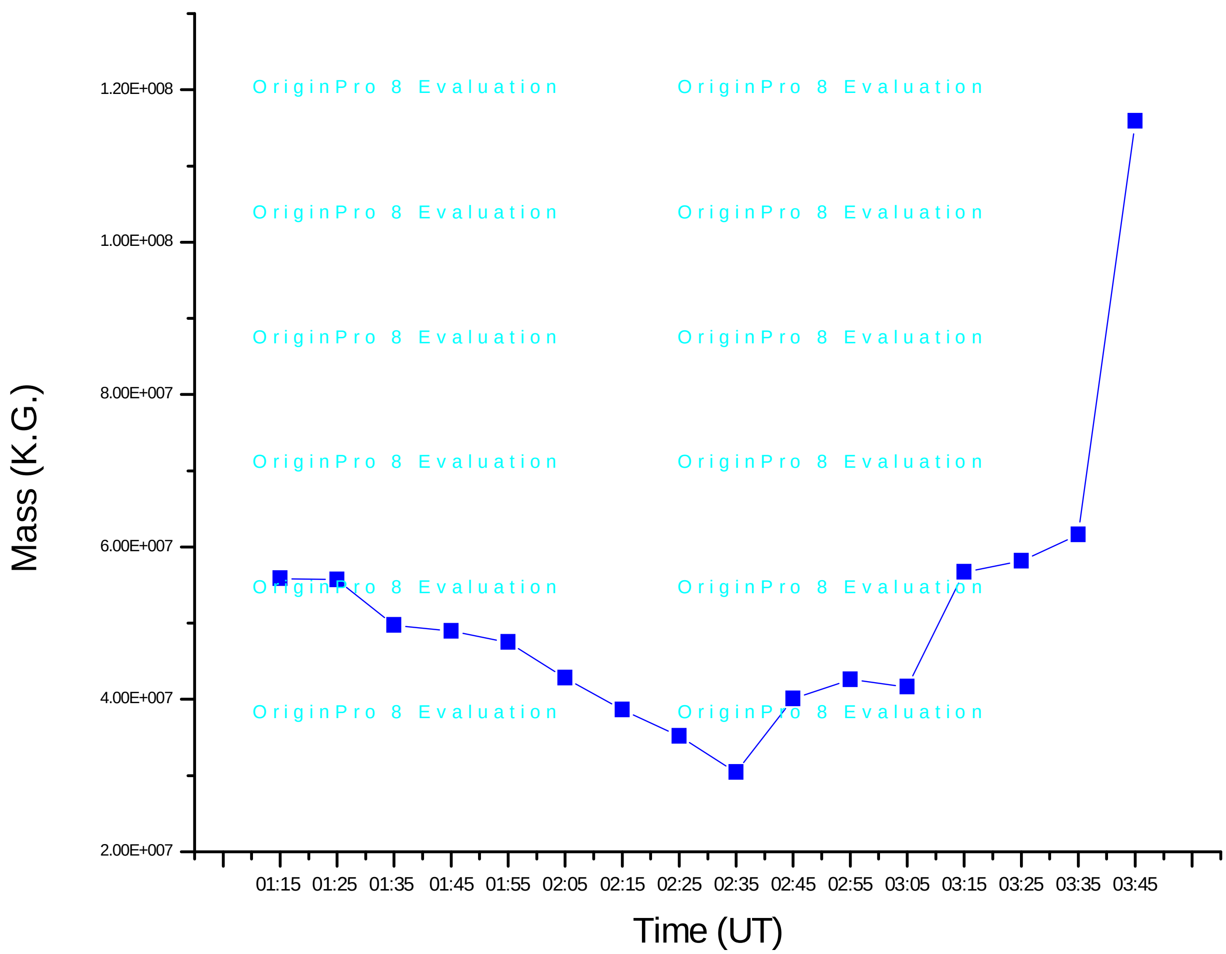
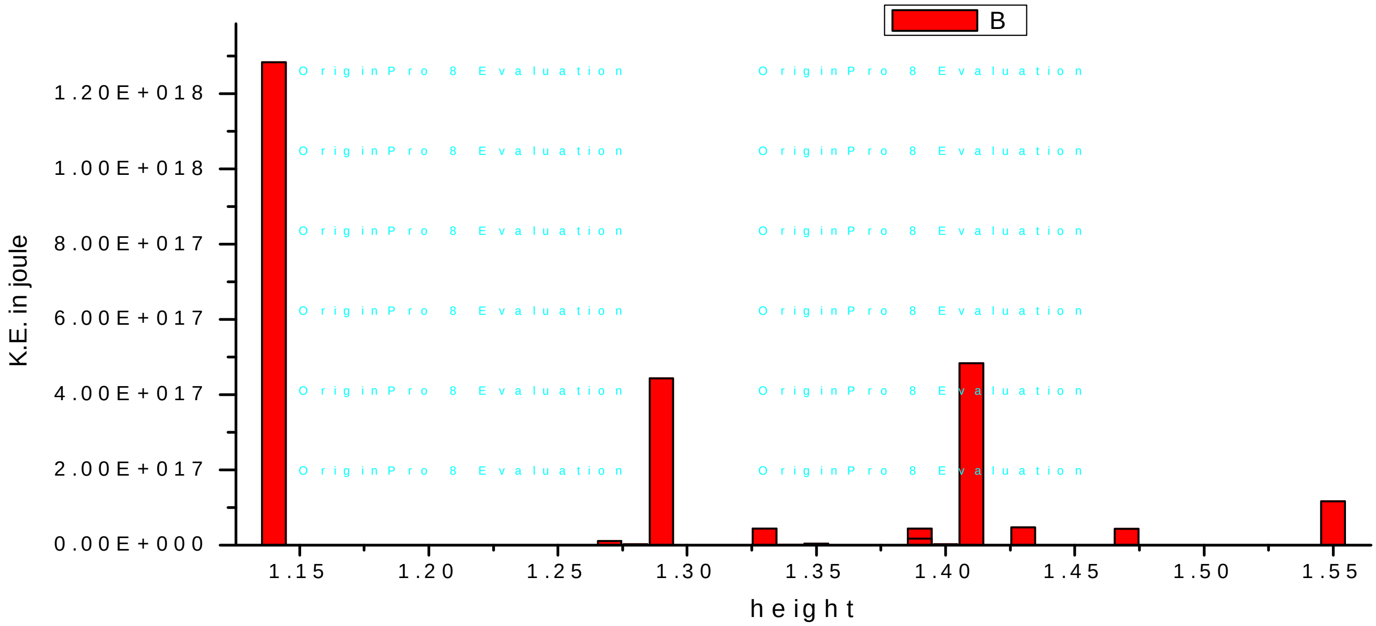


Fig-3.4: Variation of Kinetic energy and mass of prominence 7 Dec 2001 associated CMEs with respect to time.



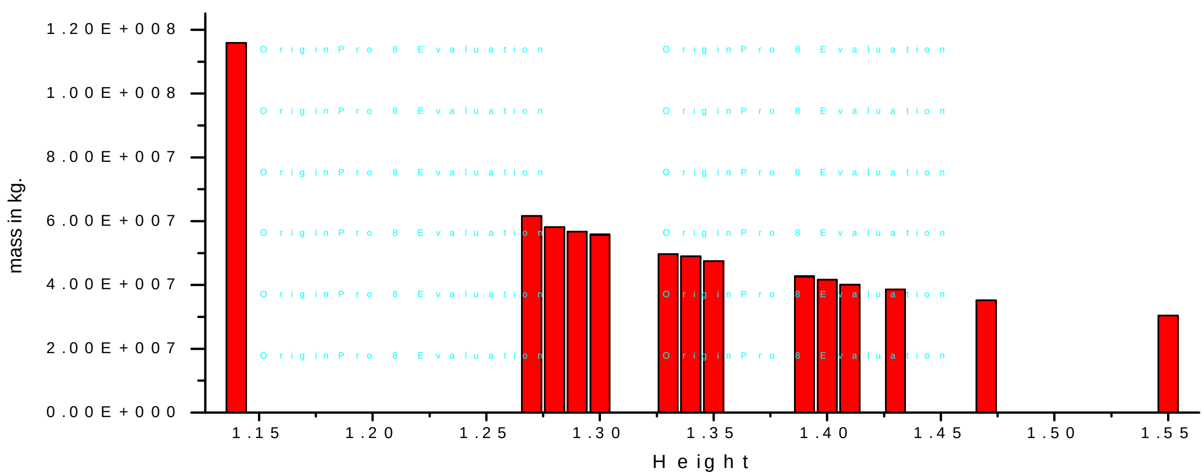
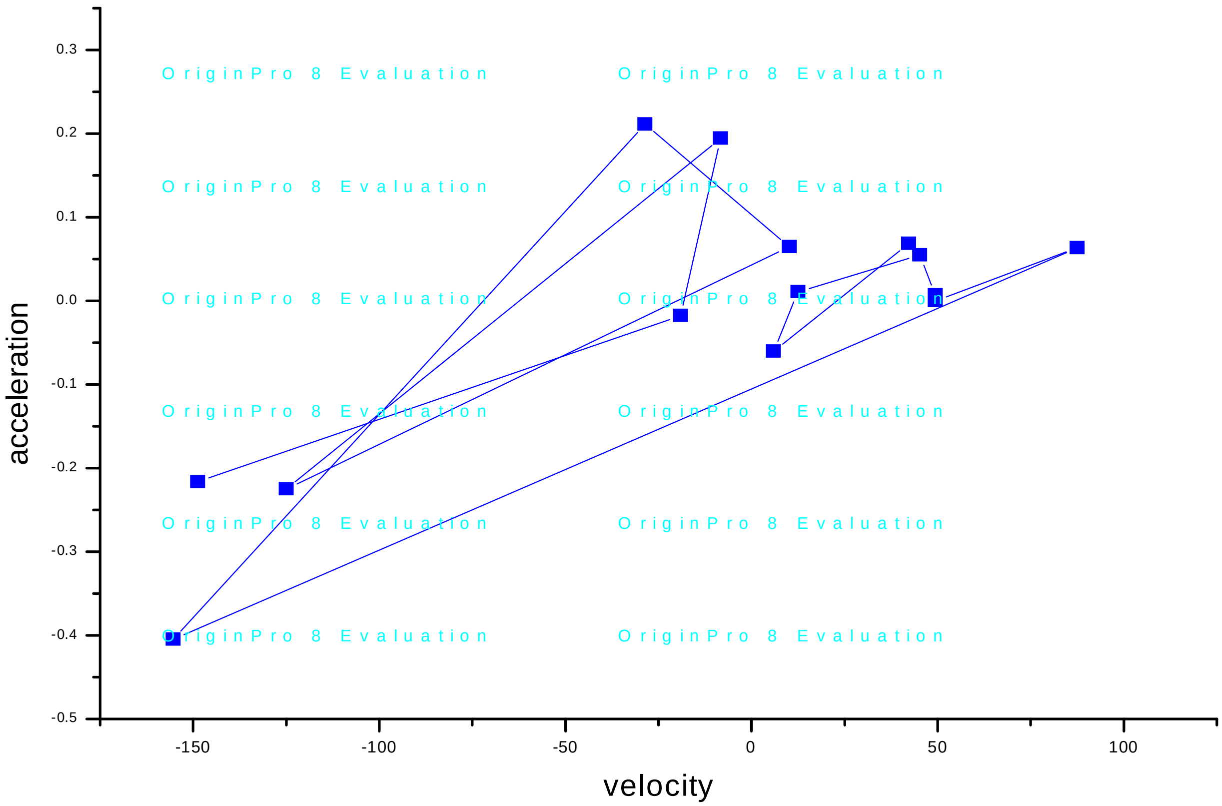


Fig-3.5: Variation of kinetic energy and mass of prominence with respect to height.



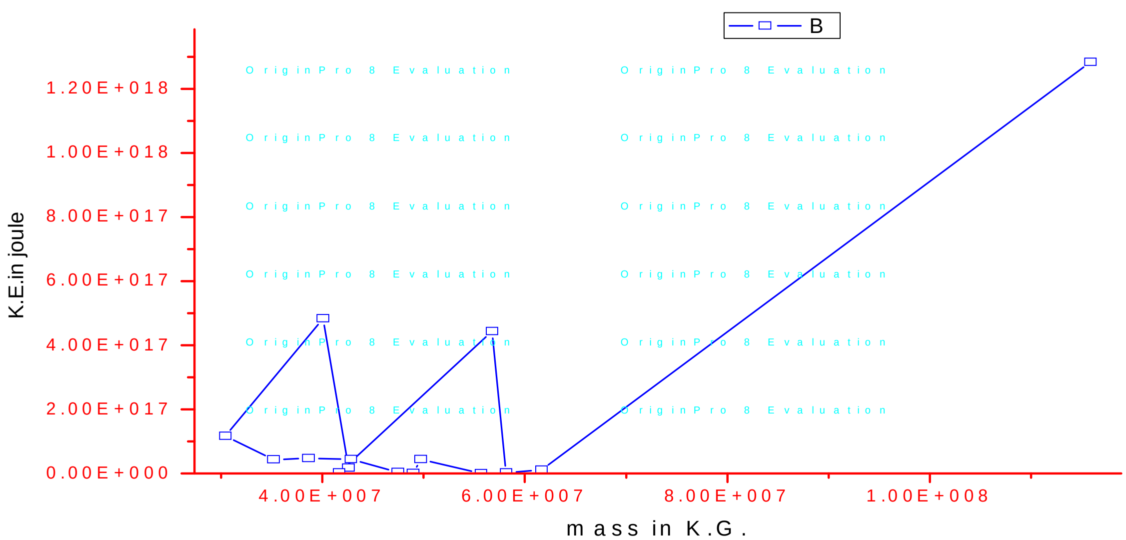


Fig-3.6: Variation of acceleration with velocity and K.E. with mass of prominence associated with CMEs. There is non-linear relation between them

3.6 Conclusions

The following conclusions are drawn from the study of prominence eruption and associated CMEs on 7 Dec 2001-

(i) The spatial and temporal correlation between prominence eruption and initiation of CME is found to be good. This analysis suggests that both the events are caused by a common disturbance.

(ii) The average kinetic energy of the CMEs is found to be 2.2×10^{30} erg (from Soho/Lasco data), whereas the average kinetic energy stored in the prominence is about 1.69×10^{24} erg (from the calculation). These values suggest that CMEs moving faster than prominence.

(iii) The mass of CMEs is 2.9×10^{15} gm (from Soho/Lasco data) and mass of prominence is 5.1×10^{10} gm (from the calculation) that means the mass of CMEs is greater than PEs. Hence PEs is the inner core of CMEs.

(iv) The associated eruptive prominence was observed to be long lived and Bar-shaped in activity for two days (6-7 Dec) prior to lift-off of the CMEs.

(v) Evidence of clear relation of the three part structure, white light CME was found with 17 GHz images.

(vi) The pre-eruptive scenario shows a bright twisted feature (7 Dec 2001) and a bright Knot with a bright straight pillar in 17GHz image at a height of 0.5 and 0.6 solar radii above the solar surface, respectively.

(vii) The Dec 7 2001 prominence is a typical example of a gradual or slowly rising type event. The initial speeds are less than 42km/sec and rise is gradual. In fact the rise is so slow that it is rather difficult to define an onset time of the CMEs.

(viii) Speeds profiles are remarkably different. The maximum velocity achieved in case of 7 Dec 2001prominence is approximately (-155.5) km/sec and the associated CMEs in the range 393km/sec.