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Evolution of the helical prominence of December 15, 1992

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Abstract. Following Vrsnak (1990), the observations of an eruptive prominence are analysed. Time evolution of height and velocity of the ascending prominence are measured. The prominence manifested helical structure and many knots. Large loop of the prominence prior to eruption has been seemingly formed by reconnections. The evolutions of the average pitch angles in the legs of the prominence and near the summit, from pre-eruptive phase to eruptive phase, are measured. The decrease of pitch angle in legs and near the summit of the prominence suggest 'detwisting'. Velocities of five selected knots are also given.

Key words : prominence—pitch angle—pitch length

1. Introduction

Solar prominences are made of chromosphere-like plasma embedded in the hot corona. At some stage of its evolution, the prominence can lose its stability and become sharply activated with material eruption. It rises up as an eruptive prominence and finally disappears. A part of its material leaves the sun, while the other part falls back down into the Sun's chromosphere. Quiescent filament activation followed by material eruption is called disparition brusque or DB which can be thermal or dynamical in nature. In the dynamic DB, the eruption takes place when the prominence attains an ascending velocity of the order of a few hundred kilometres per second. The extremely energetic phenomenon of eruption of prominences sheds light on the morphological and magnetic changes from the photospheric to the coronal regions (Hirayama 1985; Anzer1989; Rompolt 1990; Martin 1990; Schmieder 1989; Demoulin & Vial 1992).

Helical structures in prominences, the rotational motions and 'detwisting' or 'twisting' of fine structure threads are frequently observed. However, only a few quantitative analyses of pitch angle were so far reported (Valnicek 1968; Engvold, Malville & Rustad 1976; House & Berger 1987; Vrsnak *et al.* 1988). The measurements of the pitch angle from filtergrams of the eruptive prominence of August 16, 1988 were reported by Vrsnak (1990). The basic assumption made by him was that $H\alpha$ fine structure of the prominence discloses the helical structure of the prominence magnetic field governed by cylindrical or helical symmetry. He found that the decrease of pitch angle took place in the legs and summit of the prominence. However, the integral twist in the tube was constant which indicated MHD instability governing the process. The magnetic reconnection did not play an important role. Vrsnak (1990) suggested that many eruptive prominences should be studied in a similar manner, in order to provide a statistical basis for the empirical determination of parameters relevant for the eruption.

Motivated by this, we measured the pitch angles of the helices with the help of knots seen in the legs and near the summit of the eruptive prominence of December 15, 1992. This prominence was observed at the Uttar Pradesh State Observatory, Naini Tal through a 15 cm, f/15 coudé refractor equipped with a Bernhard - Halle H_α filter (passband 0.5/0.7 Å). To magnify the solar image by two times, a Barlow lens was placed near the original focal plane before the H_α filter and Olympus camera body. The filtergrams were recorded on a 35 mm Kodak Tech Pan 2415 film.

2. Morphology and kinematics

On the first filtergram of 02 12 UT, the prominence which appeared on the eastern limb covering about 10 to 30 degrees of southern latitude, showed a complicated multiloop system; some with intertwined filamentary threads cf., (Fig. 1 (a)). The position of the active region 7370 (S 08° E 79°) is at one end of the prominence (Solar Geophysical Data, No. 582 Part I, 1993). The footpoints, more than six in number showed separation among themselves of 20000 to 50000 kms. The maximum loop height in the beginning as observed was about 30000 kms. The conspicuous morphological changes in the prominence were noticed around 0245 UT. A continuous rise in the height of the prominence axis was noticed since 0455 UT. This time was assumed as t=0. Due to frequent power failures and malfunctioning of the time lapse camera we could not obtain filtergrams at a 1 minute or 30 seconds time intervals. Here we present the optimal number of filtergrams to show the prominence evolution from the pre-eruptive phase to the eruptive phase. Fig. 1 (b) clearly depicts activity near the footpoints. At first an almost vertical column was seen rising at one end while many thread - like loops were seen at the other end. The shape of the prominence was continuously changing (cf., Figs 1(c), (d)) and was ascending slowly and the helical structure could clearly be seen in Fig. 1(d). The prominence appeared to be composed of many helical loops. These loops further evolved into three larger loops (cf., Figs 1(e), (f)). After 05 10 UT, reconnections led to form two large loops which later merged into one very large loop at 05 21 UT (cf., Fig. 1(g)). This loop was seen to be composed of many bright and faint knots in its legs and near the summit and showed a continuous ascent and attained a maximum height of 270000 kms. Nine knots, five in leg A, three in leg B and one (unresolved) near the summit, were chosen to measure the pitch angle (θ) and pitch length (λ) (cf., Fig. 2). Figs 1(d – k) were chosen to measure the time evolution of pitch angles. The average pitch angles, pitch lengths and radii (r) of prominence loop in two legs and near the summit are given in Table 1. The height and velocity of the prominence axis are given in Fig. 3 and also in Table 2. The axis of the prominence was drawn after magnifying the observed filtergram by 21 times with the help of a projector. The height of the prominence axis from the solar limb was then measured. The rate of change of height with time allowed us to estimate the velocity at different moments. However, because of seeing and the telescope size, our measurements will not have an accuracy. better than 1000 kms. This will also be reflected in the velocity estimates. The velocity of five selected knots in leg A are given in Table 3.

Table 1. The pitch parameters in the legs and the summit.

	Leg A			Leg B			Summit		
t(min)	r (1000 km)	λ	θ(deg)	r (1000 km)	λ	θ(deg)	r (1000 km)	λ	θ(deg)
8	15.8	–	80	11.0	–	70	–	–	85
15	14.2	23.7	60	9.5	18.9	55	15.8	–	75
18	15.8	25.2	50	7.9	23.7	45	17.4	–	60
26	9.5	31.6	35	6.3	26.8	40	6.3	–	32
27	6.3	34.7	30	4.7	31.6	40	6.3	–	30
29	4.7	37.9	25	4.7	32.8	30	4.7	–	40
30	3.9	58.8	20	3.9	63.2	25	3.9	–	–
34	3.2	78.9	15	3.2	63.2	20	3.2	–	–

Table 2. Height and velocity of the prominence during eruption.

t(min)	height km 10^3	velocity km^{-1}
0	30	54
8	56	59
15	80	144
18	106	144
21	132	142
25	174	246
27	190	200
28	202	335
30	245	116
34	270	–

Table 3. Velocities of five selected knots (km sec^{-1}).

knot t(min)	1	2	3	4	5
27	62.8	42	105	42	231
29	113.9	410	387	410	284
30	22.8	22.8	57	218.9	280
34	184	–	–	103	122.6

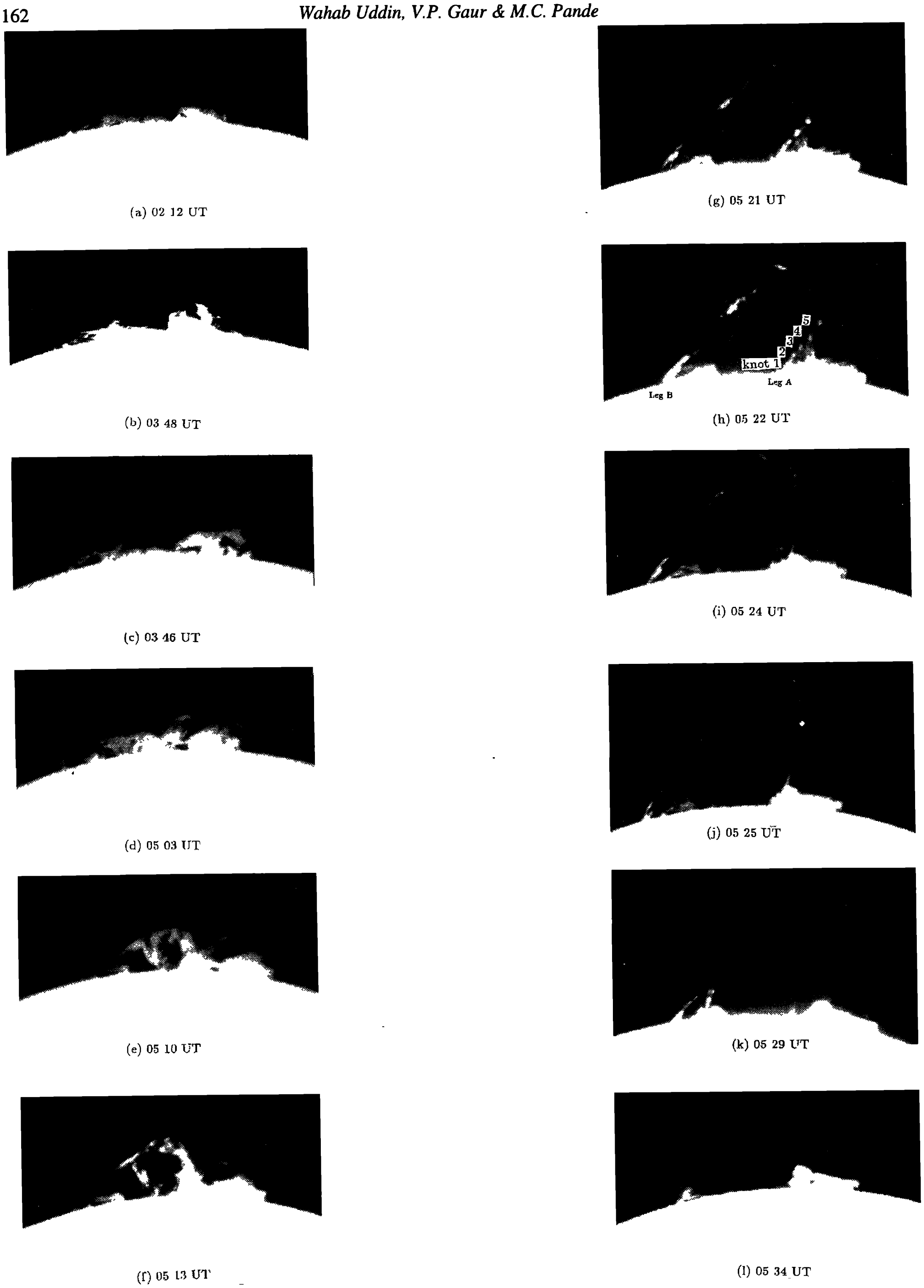

Figure 1. Some selected Hα filtergrams of the eruptive prominence on 15 December 1992.

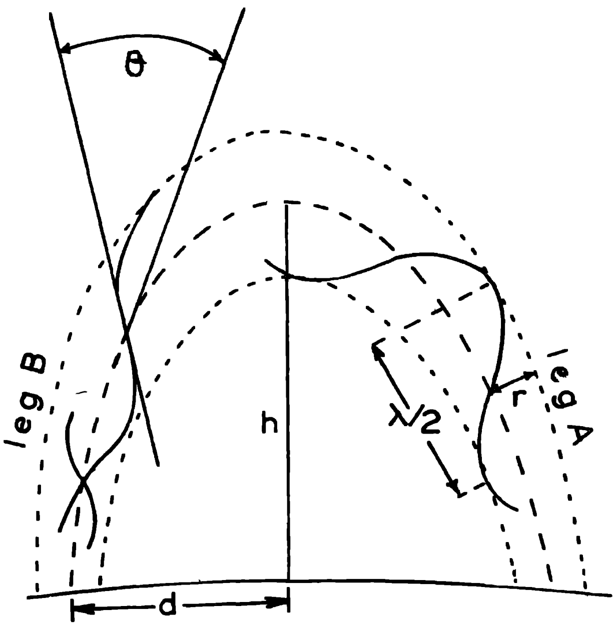

Figure 2. A helical prominence shown schematically as an elliptically curved cylinder of height h and the foot point separation of 2d. Long dashed line is the prominence axis. The cylinder radius is *r*. One helically twisted thread is indicated by the thick line. The pitch angle (θ) and half of the pitch length, ($\lambda/2$) are also shown here. The legs A and B are also illustrated.

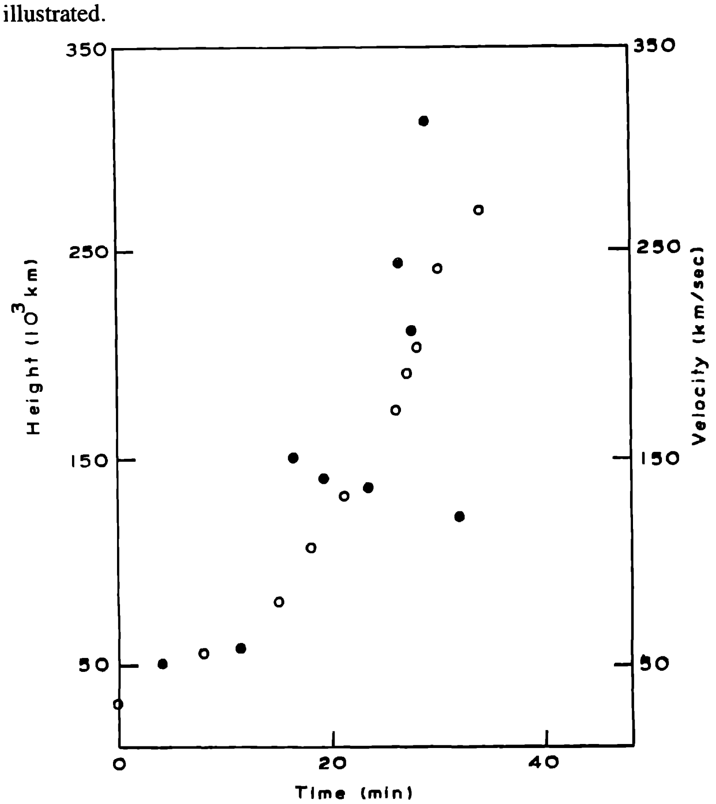

Figure 3. Time evolution of height (o) and velocity (•) of eruptive prominence.

3. Conclusions

As is evident from Table 1, the pitch angles decreased during the eruptive phase of the prominence which means that 'detwisting' occurred during this phase. In leg A, this can clearly be seen from Fig. 1 (i) (05 23 40 UT). Near the summit, the knot appeared as unresolved hence the pitch length could not be measured. Also, as suggested by Vrsnak *et al.* (1988) the accuracy of pitch measurements is quite low in case of dynamical events when the internal structure changes rapidly.

In Table 3, the velocities of five selected knots in leg A of the prominence are given as a function of time. These velocities suggest non-uniform stretching of magnetic field lines with time and at different heights of the prominence loop. The other conspicuous feature of the knots is their intensity variations with time. For example, knot number 5 in leg A in figures 1(g–k) clearly shows this aspect.

The above results may be due to oscillations in velocity and in intensity. Such oscillations observed by several investigators, could be measured by us as the recorded H_α filtergrams lacked observations at short and regular intervals.

Figs. 1(e–g) suggest that the formation of a loop-like configuration of the prominence took place after reconnections. Such a scheme of loop formation and eruption of active region prominence as suggested by Rompolt (1990) is classified as Type I eruption. Type I eruptions are also observed in quiescent prominences. Such eruptions are usually associated to flares and CMEs. From the Solar Geophysical Data (SGD), we do not find such an association in this case.

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