CHANGES OF HELICAL STRUCTURES DURING THE ERUPTION OF TWO PROMINENCES

D. ROŠA
Zagreb Observatory, HPD, Općiša 22, 41000 Zagreb, Croatia

B. VRŠNAK, V. RUŽDIJAK
Hvar Observatory, Faculty of Geodesy, Kačićeva 26, 41000 Zagreb, Croatia

A. ÖZGÜÇ
Kandilli Observatory, 81220 Çengelköy, Istanbul, Turkey

V. RUŠIN
Astronomical Institute of the Slovak Academy of Sciences, 05960 Tatranska Lomnica, Slovakia

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Abstract. Local changes of pitch angles of helically twisted Hα threads in the legs of two eruptive prominences are studied. In most of the studied prominence fine structure elements the pitch angles were changing in accordance with simple geometrical variations of the magnetic tubes (radial expansion/contraction and axial elongation). In one case a transport of twist into the expanding part of the tube was inferred, and in one other case indications of possible radial oscillations of threads were observed.

1. Introduction

"Detwisting" motions are frequently observed in the legs of eruptive prominences (Tandberg-Hanssen, 1974; Vršnak et al. 1993, and references therein). Since the magnetic field lines are anchored in the dense and inert photosphere on both sides of the prominence body, and as there are usually no indications of significant resistive processes resulting in magnetic reconnection (absence of significant heating) within the prominence body, the detwisting motions are most probably only a geometrical effect of the prominence body stretching (Vršnak et al., 1993). The changes of the pitch angles of the helically twisted fine structure threads depend on the ratio of the radial expansion rate and the axial stretching rate (House and Berger, 1987). However, one
another effect could influence the changes of the pitch angle: in the case of a nonuniformly expanding tube, a torque is exerted by the magnetic field lines with a tendency to transport the twist into expanded parts of the tube from contracted parts of the tube, i.e. leading to a nonuniform change of the pitch angle along the axis (Jockers, 1978; Browning and Priest, 1983). In this paper we present detailed observations of the changes in the Hα helicoidal structures in the legs of two eruptive prominences in order to reveal the nature of the "detwisting" process.

2. Observations

2.1. The Eruptive prominence of November 10, 1967

The prominence was observed in the Hα line at Kandilli Observatory (Turkey) from 08 55 UT to 09 43 UT. Only a part of the prominence was visible on the filtergrams suited at the centre of the Hα line, being one leg of the eruptive prominence. It consisted of several helically twisted threads with a common axis directed approximately normal to the solar surface. The rest of the prominence was probably out of the bandpass of the Hα filter due to a high radial velocity. The stretching and radial expansion of the leg were clearly exposed, while the changes of the pitch angle showed a somewhat complex "detwisting" process, as different threads were in or out the filter bandpass.

2.2. The Eruptive prominence of December 7, 1978

The prominence was observed in the Hα line at Skalnate Pleso Observatory (Slovak Republic) from 08 17 to 09 02 UT at the NE solar limb (Rušín, 1989). The two intertwined helical threads were observed in one leg of the eruptive prominence. The axis of the prominence leg was almost normal to the solar surface. A simple "detwisting" process was accompanying the prominence stretching and the radial expansion of the leg.

3. Measurements

In Figure 1 we present schematically the measured quantities: the pitch angle of a helically twisted thread (θ), the radius (R) of the helix and its pitch length (λ), and the height (h) of the studied element of the thread. The axis of the cylinder on which the threads were twisted was determined provisionally and it represents the main source of the errors in the measurements. The measurement procedure was repeated several times independently for each studied element and the values presented in the following analysis are the mean values. The pitch angle was determined either directly, or by measuring the parameters λ and r, and applying:
Fig. 1. An element of the thread (thick section of the helix) is characterized by the pitch angle ($\theta$), the radius ($r$) of the helix and its pitch length ($\lambda$), and the height ($h$).

$$\tan \theta = \frac{2R \pi}{\lambda} = X \quad (1)$$

The typical standard deviations for the values of the pitch angles were in the order of $5^\circ$.

4. Results

For each studied element we have drawn graphs showing the time evolution of each parameter. Here we present only two typical examples. In all cases the parameter $h$ was increasing in time, i.e. revealing a global expansion of the prominence. Unfortunately, in both prominences it was not possible to follow the changes of the general geometry and the kinematics of the prominence eruption, as in both cases
Fig. 2. The evolution of the parameters $X = \tan \theta$, $\lambda$, and $r$ for an element of the prominence of November 10, 1967.
Fig. 3. The evolution of the parameters $X = \tan \theta$, $\lambda$, and $r$ for an element in the prominence of December 7, 1978.
only one leg of the prominence was clearly visible. The parameters $\lambda$ and $r$ were most often increasing simultaneously, leading to various types of changes of the parameter $X = \tan \theta$. In one case the parameter $\lambda$ was decreasing.

In Figure 2, we present the evolution of the parameters $X = \tan \theta$, $\lambda$ and $r$ for an element of the prominence of November 10, 1967, and in Figure 3 the same parameters for an element in the prominence of December 7, 1978. In Figure 4, we present the dependence $\lambda(h)$ for the case of decreasing $\lambda$ in an element of the prominence of November 10, 1967. In Figure 2 we can see the simultaneous increase of the length (Figure 2b) and radius (Figure 2c) of the studied element. Such a change of the geometry results in average in a constant pitch angle (Figure 2a). Note the "oscillations" of the pitch angle around this average value (the variations are larger than the uncertainty of the measurements). In Figure 3a we can see the case of a decreasing pitch angle. The stretching (Figure 3b) dominated over the radial expansion (Figure 3c): the element was stretched almost five times while the final value of the radius was only 30% larger than the initial one.

In Figure 4 an interesting case of pitch length ($\lambda$) decrease with height ($h$) is demonstrated. Since the prominence was stretching (increasing $h$) globally, one should
Fig. 5. The classes of the changes of geometry of an element of a helically twisted thread: (a) stretching dominates ($\Delta \theta < 0$); (b) radial expansion dominates ($\Delta \theta > 0$); (c) "proportional expansion" $\Delta r \sim \lambda$ ($\Delta \theta = 0$); (d) transport of twist into an expanded element of the tube ($\Delta r > 0$, $\Delta \lambda < 0$, $\Delta \theta > 0$).

expect that each element of the prominence would be stretched. However, if stretching is accompanied by radial expansion so that the rate of expansion depends on the position along the prominence, one should expect transport of twist into more expanded parts, on expense of the less expanded parts of the prominence. Generally, the change of the pitch angle can decrease or increase, depending on the ratio of the stretching and expansion rate, and the transport of twist process could be erroneously identified with purely geometrical causes. However when the pitch length is decreasing, the process of twist transport is unambiguously disclosed.

5. Conclusion

In Figure 5 we schematically present different classes of the observed changes of the pitch angles in helical elements of erupting prominences. The nature of the first three classes is purely geometrical (kinematical). The first class (Figure 5a) represents the case when stretching dominates, so the pitch angle decreases. Such a change is usually attributed as "detwisting" motion, although only spectroscopic observations can reveal eventual rotational motions. If rotational motions are absent, the change of the pitch angle represented by the first three classes in Figure 5 does not really represent detwisting.
Most interesting is the case sketched by Figure 5d. It undoubtedly represents the process of transport of twist into the expanded part of the prominence body. It is the only case in the studied sample where twist transport (dynamical process caused by "magnetic torque") cannot be confused with the purely geometrical changes caused by simple kinematical characteristics of radial expansion and stretching.

References


PROMJENE HELIKOIDALNOG USTROJSTVA TIJEKOM ERUPCIJE DVJU PROMINENCIJA

D. ROŠA
Zagreb Observatory, HPD, Opatačka 22, 41000 Zagreb, Croatia

B. VRSNAK, V. RUŽDJAK
Hvar Observatory, Faculty of Geodesy, Kačićeva 26, 41000 Zagreb, Croatia

A. ÖZGÜÇ
Kandilli Observatory, 81220 Çengelköy, Istanbul, Turkey

V. RUŠIN
Astronomical Institute of the Slovak Academy of Sciences,
05960 Tatranska Lomnica, Slovakia

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