**Observation of an Instability in a 'Quiescent' Prominence**

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**ABSTRACT**

**Aims.** We present the detection of a bubble-like cavity traveling through a quiescent prominence.

**Methods.** \(\text{H} \alpha\) slit-yaw images were taken together with \(\text{Ca II} 8542\) spectra using an image intensifier.

**Results.** The \(\text{H} \alpha\) emission in the cavity is more than 16 times smaller than in its surroundings. The cavity propagates almost with the phase-velocity of MHD compressive waves. We suggest a disruption of the lateral magnetic stability criterion in the Kippenhahn-Schlüter (or Kuperus-Tandberg-Hanssen) model. The \(\text{Ca II} 8542\) spectra indicate a material outflow along the lines of force up to 12 km/s.

**Key words.** Prominences - quiescent - bubble - cavity - magnetic field instability - compressive waves

1. **Observing Procedure**

The observation of prominence spectra with high spatial, spectral and time resolution is generally limited by the long exposure times required. For the \(O= 45\) cm Locarno telescope with its 10 m spectrograph (\(\approx 0.18\) Å/mm) the observation of the \(\text{H} \alpha\) emission line in prominences would lead to an exposure time of several minutes. But the use of a new type image intensifier (two-step proximity-focused 'Bendix') attached to the focal plane of the spectrograph, reduces the exposure time to about one second. The image produced by the intensifier is taken on a Kodalith film at tight contact to the fiber-optics output of the image intensifier. Its 24 mm aperture permits observations of Doppler displacements up to \(\pm 120\) km/s in \(\text{H} \alpha\); its resolution of about 35 lines/mm allows to spatially resolve 1 arcsec (0.125 mm) and spectrally 15 mA (0.08 mm for \(\text{H} \alpha\); see also Stellmacher and Wiehr (1972).

2. **Description of the Event**

On October 12, 1971 we observed a quiescent prominence at the eastern limb (solar latitude 45\(^o\) S) for a spectral analysis of various emission lines. The frequent configuration of an arch-like lower boundary of the prominence body unexpectedly ascended at 13.45 UT. The series of \(\text{H} \alpha\) slit-yaw pictures (pass band 0.5 Å) indicates a projected motion between 7 and 17 km/s (Fig. 1). At 14.15 UT the lower part of the elevated arch closed up, thus forming a bubble-like 'cavity' within the prominence. This cavity continued to move upwards and contracted until it disappeared at 15.40 UT. The original overall configuration of the prominence was then restored and lasted the following day (Fig. 3).

3. **Spectra**

3.1. **Line shifts**

Increasing haze unfortunately hampered most of the spectral observations with the image intensifier. Only the infrared \(\text{Ca II} 8542\) emission line was sufficiently exposed and could thus be analyzed after substantial contrast enhancement of the Kodalith film (Fig. 2). The prominence spectra taken before the formation of the cavity ascension (No. 3-7 in Fig. 2) show the characteristically wiggled lines, which equally occurred on the following day in both emissions \(\text{Ca II} 8542\) and \(\text{H} \alpha\) (Fig. 3).

At the beginning of the cavity ascension, Doppler shifts of \(v_r \approx 3\) km/s occurred just above the lower boundary of the arch (points 3 and 4 in spectrum 3). During the ascension of the cavity, these shifts then occurred all over the prominence body, but increased at up to 13 km/s at the boundary of the cavity (cf., locations 10/3 and 13/2). They finally disappeared after the prominence became again stable at about 16 UT.

3.2. **Line widths**

Measurements of the half-widths at 1/e-intensity, \(\Delta \lambda_e\), are given in Table 1 together with the corresponding radial velocities, \(v_r\). A correlation between both (as discussed by Engvold, 1972) could not be established. Most of the highly shifted line profiles appear strongly broadened (10/3, 11/1, 11/2, 12/1, 13/2, 14/7), corresponding to non-thermal velocities of up to \(v_{nth} \approx 5\) km/s if \(T_{kin} = 6000\) K (Stellmacher, 1969). Some of these highly diffuse and asymmetric profiles show several peaks, which may indicate a superposition of different Doppler shifted emissions from individual prominence filaments with \(v_{nth} = 1 - 2\) km/s.

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Fig. 1. Hα slit-yaw images of the 'cavity' event on Oct. 12, 1971, in the 'quiescent' prominence at the east limb, 45°S. Due to problems with the slit-yaw camera, the 15.15 UT phase is given as a visual observation.

Fig. 2. Hα spectra of Ca II 8542 taken during the cavity event; \( \lambda \) increases to the top. The slit positions are entered in the corresponding Hα images from Fig. 1; scan locations are indicated in each spectrum.

4. Emission inside the cavity

From the Ca II 8542 spectra 11, 12 and 15 it can be seen that the cavity represents a real disappearance of the emission and not a Doppler shift 'off-band' the Hα filter of the slit-yaw imaging device. For an estimate of the residual Hα emission inside the bubble-like 'cavity', we take as a lower limit for the detection of any prominence emission the aureole intensity of \( 3 \cdot 10^{-3} \) of the continuum intensity at disk center. The residual emission inside the cavity will then be smaller than 0.06 of the mean intensity of the prominence; the Hα emission is thus reduced by at least a factor of 16.
with respect to the surrounding emission of the undisturbed prominence body.

5. Discussion

In the picture of recent prominence models (e.g. Kippenhahn and Schlüter, 1957, Kuperus and Tandberg-Hanssen, 1967; Anzer and Tandberg-Hanssen, 1970) the magnetic field lines within a quiescent prominence are almost parallel to the solar surface. The bubble-like cavity would then have propagated more or less perpendicular to the lines of force. It is therefore rather suggestive to consider MHD compressive waves as physical origin.

Their phase velocity is \( v_{MHD} = \sqrt{v_{\text{sound}}^2 + v_{\text{Alfven}}^2} \) where \( v_{\text{sound}} = 7 \text{ km/s if } T = 6000 \text{ K for the prominence. The observed 7-17 km/s motion would then require an Alvén velocity of } 3 \text{ km/s} \leq v_A \leq 13 \text{ km/s}. \) This, in turn, corresponds to a (reasonable) strength of the prominence magnetic field of \( 0.5 \text{ G} \leq B \leq 1.5 \text{ G} \), if \( q = 1.8 \cdot 10^{-13} \text{ g/cm}^3 \) (in agreement with observed \( N = 10^{11} \text{ cm}^{-3} \)).

The Doppler displacements at the 'cavity' border indicate a lateral outflow of prominence matter, caused by the bubble-like disturbance. It had already been suggested by Kippenhahn and Schlüter (1957) that relatively small disturbances of the supporting magnetic field may be sufficient to violate their stability criteria. In our case the stability criterion against lateral displacements may be disturbed, thus causing a lateral material outflow along the lines of force. The rather good agreement between the observed radial velocities (up to 12 km/s) and the sinking velocity of prominence matter through the corona (Unsöld, 1970) seems to support this idea.

Fig. 3. H\( \alpha \) and Ca II 8542 emissions in the same prominence taken the next day; \( \lambda \) increases to the top.
Further observations of such bubble-like instabilities in ‘quiescent’ prominences would be necessary to improve our knowledge about their physical origin and the stability criteria of prominences.

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Table 1. Doppler velocity, $v_r$, and half-width at 1/e intensity, $\Delta\lambda_e$, of for each spatial location in the Ca II 8542 spectra Fig. 2; brackets indicate estimates for location with too faint Ca II emission.

| Spectr. | Scan | $v_r$ [km/s] | $\Delta\lambda_e$ [mA] |
|---------|------|--------------|------------------------|
| 3       | 1    | 0            | 65                     |
|         | 2    | 1.4          | 95                     |
|         | 3    | -3.7         | 80                     |
|         | 4    | 2.8          | 80                     |
|         | 5    | -1.2         | 95                     |
|         | 6    | 0.9          | 90                     |
| 5       | 1    | -2.5         | 75                     |
|         | 2    | -0.9         | 90                     |
|         | 3    | -2.3         | 80                     |
|         | 4    | 1.0          | 115                    |
|         | 5    | 0            | 75                     |
| 7       | 1    | -5.3         | 85                     |
|         | 2    | 0            | 90                     |
|         | 3    | 2.1          | 75                     |
|         | 4    | (0)          |                        |
| 10      | 1    | -2.1         | 95                     |
|         | 2    | (-7.0)       |                        |
|         | 3    | -10.5        | 130                    |
|         | 4    | 2.1          | 105                    |
|         | 5    | 6.7          | 115                    |
|         | 6    | 0            | 125                    |
| 11      | 1    | -6.7         | 125                    |
|         | 2    | 8.8          | 125                    |
|         | 3    | 0            | 80                     |
|         | 4    | 2.1          | 75                     |
| 12      | 1    | -8.8         | 80                     |
|         | 2    | 0            | 70                     |
| 12      | 1    | -8.8         | 80                     |
|         | 2    | 0            | 70                     |

| Spectr. | Scan | $v_r$ [km/s] | $\Delta\lambda_e$ [mA] |
|---------|------|--------------|------------------------|
| 12      | 3    | -4.2         | 100                    |
|         | 4    | -2.1         | 80                     |
| 13      | 1    | -2.1         | 100                    |
|         | 2    | -12.0        | 100                    |
|         | 3    | -4.2         | 85                     |
|         | 4    | -2.1         | 80                     |
| 14      | 1    | (0)          |                        |
|         | 2    | (2.1)        |                        |
|         | 3    | (4.2)        |                        |
|         | 4    | (-8.8)       |                        |
|         | 5    | -4.2         | 135                    |
|         | 6    | -2.1         | 115                    |
|         | 7    | -10.5        | 150                    |
| 15      | 1    | (-5.2)       |                        |
|         | 2    | 4.2          | 85                     |
|         | 3    | (-8.4)       |                        |
|         | 4    | 0            | 115                    |
|         | 5    | -2.1         | 95                     |
|         | 6    | 2.1          | 75                     |
|         | 7    | -2.1         | 95                     |
| 16      | 1    | (-6.7)       |                        |
|         | 2    | (5.2)        |                        |
|         | 3    | -4.2         | 95                     |
|         | 4    | 6.6          | 65                     |
|         | 5    | -2.1         | 110                    |
|         | 6    | 0            | 100                    |
| 17      | 1    | -2.3         | 70                     |