Quasi-periodic Velocity Fluctuations in Eruptive Prominences Observed by AIA/SDO

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Outline

We present an investigation of prominences behavior during eruption. Variations in the distribution of their velocities are detected at altitudes < 0.6 solar radii. Detailed analyses are carried out for 304Å Solar Dynamics Observatory/Atmospheric Imaging Assembly (SDO/AIA) observations. To track prominences behavior during eruptions, 41 events in the period 2010 – 2017 are studied. To follow the rising of a filament on higher altitudes (up to 32 solar radii), Solar and Heliospheric Observatory/Large Angle and Spectrometric Coronagraph (SOHO/LASCO) data are also inspected. They are used to obtain kinematic profiles of eruptions. Obtained height-time and speed-time plots of the eruptions show velocity fluctuations in 83% of the explored cases, detected only in SDO/AIA field of view, but not in any of the prominences observed at higher altitudes by SOHO/LASCO. Time intervals between fluctuations and heights at which they are detected are estimated. Strong periodicity cannot be determined.

Observations

Observatory	SDO	SOHO
Instrument	AIA	C2 & C3
Channel	HeII 304 Å	white-light
Spatial resolution	~ 1".5	23" & 112"
Cadence [min]	5	12
FOV [solar radii]	≤ 0.6	2-6 & 3.7-32

Table 1. Details about the two space-based telescopes used as main source of observational data.

Data Processing

Since the structures of EPs are complex and there is often no coherent leading edge, measurements of the kinematic properties of EPs require accurate determination of the highest part of the prominence, its position, and its tracking during the eruption. For data analysis we obtained an IDL procedure based on the SolarSoftware package.

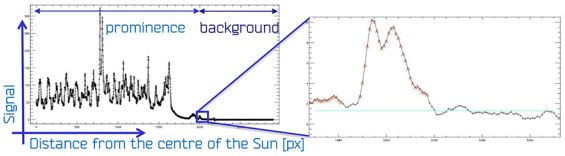
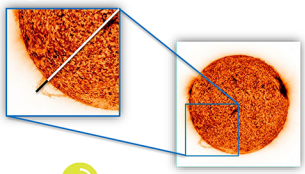


Fig. 1 (left). Defining the prominence–background boundary

Fig. 2 (right). Highest point of the EP



Primary processing of the images

Defective pixels, flat-field, heating noise and cosmic rays impact corrections.

Plotting the mean signal profile

...of a chosen highest point and the ambient ± 3 lines.

Defining the background signal part of the curve

Zooming the plot near the prominence–background boundary and indicating the points that are certainly not part of the EP signal.

Calculating the mean background signal

... and the standard deviation (σ). Background signals lie between 0.6 and 3.8 with a standard deviation of 0.3 – 2.0.

Defining the prominence–background boundary

The 3σ interval around the mean value of the signal is used to distinguish between the background noise and the prominence signal close to the edge of the filament.

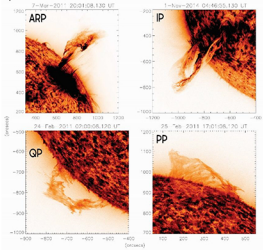
Determination of the highest point of the EP

... and the measurement error.

Prominences sample

We investigate the behavior during eruption of 41 prominences. The events are not specially selected in the sense that the only criteria applied are that the eruptions were observed on the solar limb and had to have happened in the period 2010 – 2017 (after launching the SDO mission). The kinematic properties of filaments observed on the disk are not subject of the current research.

Fig. 3. Examples of different types of EP: ARP – active region prominences, IP – intermediate prominences, QP – quiescent prominences, PP – polar prominences.



		EP types				
Characteristics	Category	All	ARP	IP	QP	PP
Associated ARs	Yes	14	8	6	0	0
	No	27	0	0	17	10
Associated CMEs	Yes	29	5	5	12	7
	No	12	3	1	5	3
Location	Mid-latitudes	31	8	6	17	0
	Polar latitudes	10	0	0	0	10
Symmetry	Symmetric	19	4	5	6	4
	Asymmetric	22	4	1	11	6
Eruption type	Full	15	3	4	6	2
	Partial	15	2	1	6	6
	Confined	11	3	1	5	2
LASCO visibility	C2 only	3	0	1	2	0
	C2 & C3	7	2	0	4	1

Table 2. Distribution of the EPs from the explored sample in different groups and categories.

SDO/AIA measurements

$0 - 0.6R_\odot$

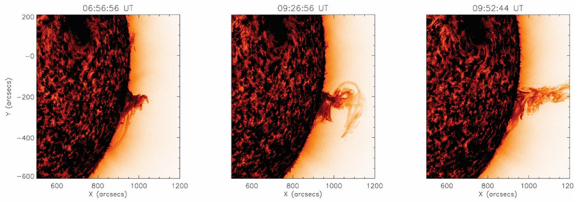


Fig. 4. The EP from 2010 August 7 as observed from AIA 304 Å.

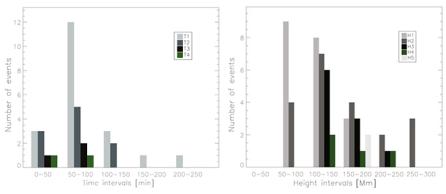


Fig. 6. Distribution of the:
- left: time intervals between the fluctuations according to their duration (T1 – time between the first and the second fluctuation of different EPs, T2 – time between the second and the third variation of EPs, etc.).
- right: intervals between the fluctuations according to the deceleration height at which they occur (H1 – the height of the EP at which the first fluctuation occurs, H2 – the height of the EP at which the second fluctuation occurs, etc.).

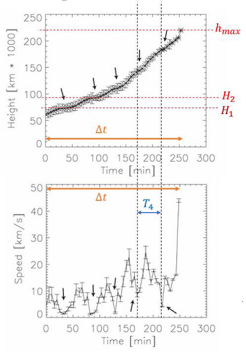


Fig. 5. Height–time (up) and speed–time (down) plots of the EP from 2010 August 7 after smoothing the data. Time intervals of the observed fluctuations are marked on the speed – time plot with horizontal segments below the curve.

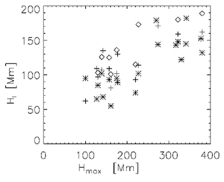


Fig. 7 The relationship between the maximum height of EPs, h_{max} and the deceleration heights at which velocity variations are detected H_i ($1 \le i \le 3$). Different symbols note the first H1 (starlet), the second H2 (cross), and the third H3 (rhombus) fluctuations of the velocity.

Pearson correlation coefficients: $r_{H1} = 0.80,\ r_{H2} = 0.75, r_{H3} = 0.75$

Minimal determination coefficient: $r_{min}^2 \times 100 = 56\%$

SOHO/LASCO measurements

$2 - 32R_\odot$

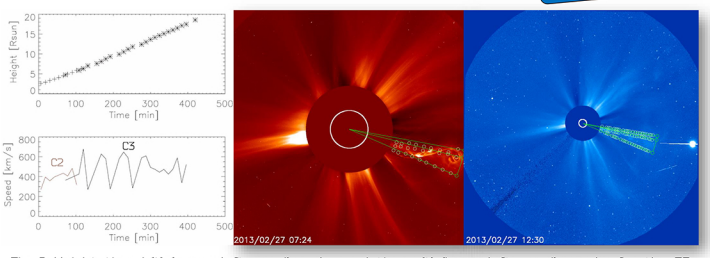


Fig. 8. Height–time h(t) (upper left panel) and speed–time v(t) (lower left panel) graphs for the EP from 2013 February 27 in LASCO C2 (middle panel) and C3 field of view (right panel).

Conclusions

- After analyzing the height – time and speed – time plots of 41 EPs using AIA/SDO data, velocity fluctuations of the rising prominence material are detected in 34 cases (83%)
- A periodicity could not be found as time intervals lie in the range 31 – 244 minutes. The most frequent time intervals between fluctuations are those with a duration between 50 – 100 minutes.
- The heights at which fluctuations are observed vary between 55,000 – 296,000 km. The first variation happens usually in the range 50,000 – 100,000 km and the following ones between 100,000 – 150,000 km.
- The influence of the maximal height the EP reaches on the deceleration heights at which velocity variations are observed is significant in >56% of the cases.
- Fluctuations are not detected when analyzing the behavior of 10 EPs that can be tracked at higher altitudes in LASCO/SOHO C2 and C3 fields of view.

The results of the current study are part of a PhD thesis "Research on the destabilization and eruption of prominences/filaments in solar active regions", defended in the Institute of Astronomy, BAS (September 2019), and are published in Tsvetkov, Ts., Petrov, N.. Quasiperiodic Velocity Fluctuations in Eruptive Prominences Observed by AIA/SDO. The Astrophysical Journal, 893, 1, 2020.

Acknowledgements

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