Cold plasma rotation in the tornado-like prominence of July 13, 2014: a real motion or an illusive effect?

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Abstract: We analyze in a case study the tornado-like prominence of July 13, 2014 which shows changing position in the SDO/AIA imaging at EUV wavelengths, using the Hα 2D spectroscopy data acquired with the CoMP-S instrument (Lomnicky Stit Observatory - LSO, AISAS, Slovakia). The aim of the study is to address the question whether this structure is a real tornado (prominence leg plasma rotating around central axis) or we just observe illusive signatures of an apparent rotational motion, like oscillation. Our case study results indicate that: a/ the detected Doppler shifts do not show a permanent blue/red-shift pattern along the vertical axis of the structure during the whole 45 min observing time interval, b/ the present variations of the Doppler shifts (± 4 km/s) are not in general clearly correlated with the Hα integral line emission of the structure, c/ the Doppler shift variations do not show any regular oscillatory behavior. These results lead to conclusion that the Doppler shifts of this particular tornado-like structure cannot be interpreted as real cold plasma rotation around the vertical axis of the structure. However the purely imaging SDO/AIA observations show clear illusive vortical motions in this tornado-like structure. We suggest that the 'vortical illusion' (Panasenco et al., 2014) - a combination of the counter-streaming flows in the prominence threads and possible radiative transfer effects - are causing the apparent rotational motion of this tornado-like structure.

Introduction

Recent observations of the SDO/AIA instrument (Lemen et al., 2012) have revitalized phenomenon of solar tornado-like prominences (Pettit, 1932). These tornado-like structures, seen as vertical prominence legs above the solar limb, are showing changing positions in the SDO/AIA imaging suggesting a rotational motion around their axis (Panasenco et al., 2014; Mghebrishvili et al., 2015; Levens et al., 2016; Schmieder et al., 2017). Such tornado rotation around its axis was spectroscopically confirmed from hot plasma emission surrounding the structure (Su et al. 2014; Levens et al. 2015) using the Hinode/EIS spectrometer (Kosugi et al., 2007) though Young et al. (2012) pointed out that such rotation could be caused by an instrumental effect. On the other hand, the cool material ($T \sim 10^4$K) emission does not present clear signatures of rotation in two investigated cases so far (Orozco Suarez et al., 2012; Schmieder et al., 2017). Panasenco et al. (2014) explained the apparent vortical motion in prominences - only observed in projection at the limb - as counterstreaming flows giving the illusion of rotation. We try to address the question, using the LSO/CoMP-S spectroscopic obsevations of a similar structure, whether it is a real tornado or we just observe illusive signatures of an apparent rotational motion.

The target tornado-like structure: SDO/AIA and LSO/CoMP-S data

- July 13, 2014, south from AR 12110, above the SW limb: [+735", -635"]
- visible as a dark structure in all SDO/AIA UV channels (except 9.4 nm)
- the dark structure is rooted vertically in front of the limb (Fig. 1)
- plane-of-sky motion in several parts of the structure (Fig.3, upper panels)
- SDO/AIA dark structure ~ CoMP-S Hα integral line emission structure: a clear coincidences of patterns

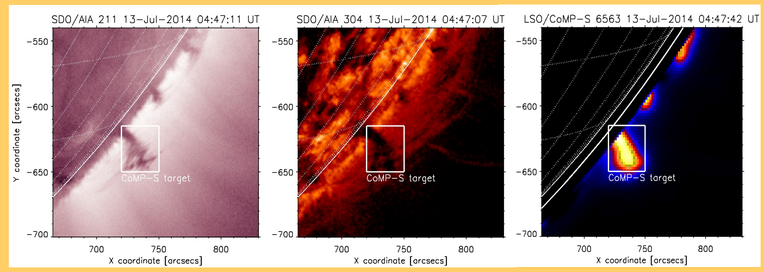

Fig. 1. The target tornado-like structure of 2014/07/13 (04:47 UT, [+735",-635"], position angle 235°): the SDO/AIA 21.1 nm and 30.4 nm channels (left and middle panels) and the LSO/CoMP-S Hα integral line emission (right panel).

LSO instrumentation & CoMP-S observations

Instrumentation:

- ZEISS 200/3000 Lyot coronagraph (Lexa, 1963)
- CoMP-S instrument: tunable 4-stage Lyot filter with Stokes polarimeter (Kučera et al., 2011)

CoMP-S Observations:

- date/time/observer: 2014/07/13: 04:47–05:32 UT, J. Kavka
- FoV: 800" x 600", position angle 235°
- spectral line: Hα 656.28 nm (9 points, 0.025 nm step, 98 scans)
- filter passband width: FHWM = 0.081 nm (measured)
- exposure time: 50 ms, scan time: 22 s
- detector: PCO sCMOS camera: 2560*2160 6.5 μm pixels

CoMP-S Data reduction:

- photometric data reduction
- Stokes I parameter data only
- 4x4 pixel binning for the resulting 1.33"/px spatial sampling
- sky background and the instrumental scattered light removed
- post-facto image jitter correction
- rest line wavelength correction
- Gaussian profile fitting to the individual Hα spectral line profiles
- temporal (3-scan) smoothing of the Gaussian fit parameters
- sub-arcsecond co-alignment to the SDO/AIA coordinates

The tornado-like structure zoom

- A zoom area just around the SDO/AIA image of the tornado-like structure itself (Fig. 2)
- the CoMP-S data mask: a radial overocculting for 13" above the solar limb
- a manually introduced Hα integral line emission mask (> 900 a.u.) leading to the CoMP-S structure body covering the whole SDO/AIA 21.1 nm channel structure body (Fig.2)
- the masked zoom area filled with 20 adjoining 2" wide and 52" long pseudo-slits (parallel to the local limb) for an individual time-space analysis of the target tornado-like structure evolution
- two pseudo-slits (#10 and #16) selected in the target structure for an illustrative display of the time-space cuts (Fig.3)

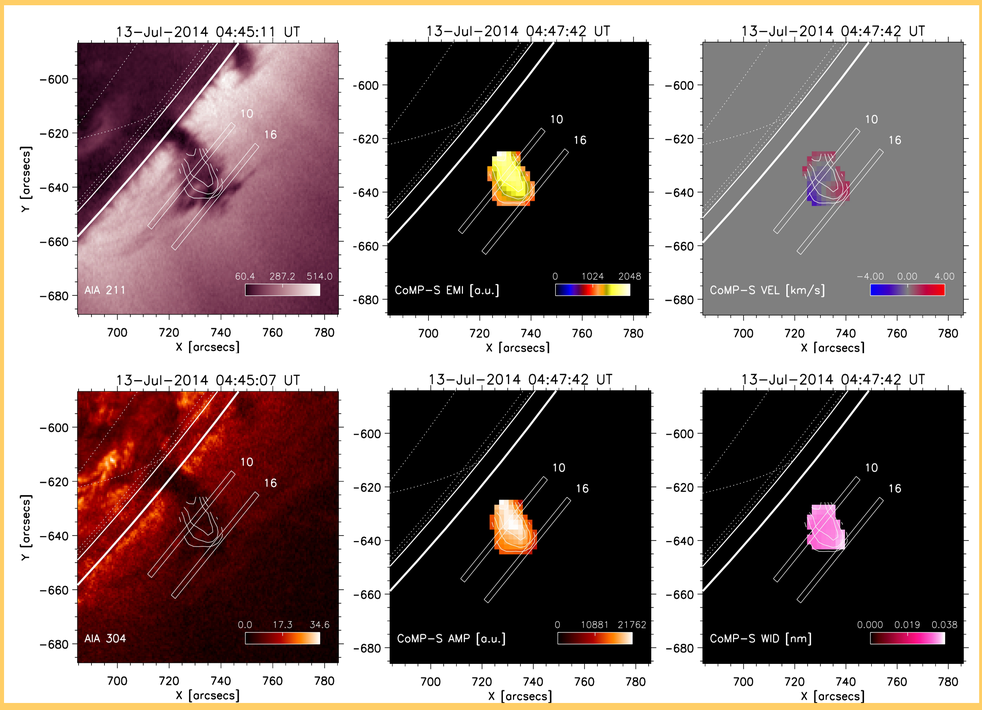

Fig. 2. The target tornado-like structure at the beginning of the CoMP-S measurements: the SDO/AIA 21.1 nm and 30.4 nm channels (left panels) and the LSO/CoMP-S Hα line Gaussian fit parameters: EMI – the integral line emission, VEL – the Doppler shift, AMP – the Gaussian amplitude, WID – the line width (middle and right panels). The Hα total line emission mask is applied (white contours in all panels). The thick white line marks the Lyot coronagraph diapraghm edge. Two narrow rectangles give positions of the pseudo-slits #10 and #16.

Motions in the target tornado-like structure

- Two representative pseudo-slits (#10 and #16) selected for presentation of results in a core and at the top of the CoMP-S structure body (Fig.3, left and right panels, respectively)
- clear appearent vortical motions in the SDO/AIA intensity movies[1] lead to a typical time-space behaviour of this tornado-like structure: variable/inclined tracks in the intensity vatiations (Fig.3, the top panels)
- the Hα line emission location is changing relatively to the AIA 21.1 and 30.4 nm dark structure (Fig. 3, overlays in the top panels)
- the Doppler shifts **do not show a permanent blue/red-shift pattern** along the vertical axis of the structure during the whole observing time interval although there are short time intervals (~10 minutes) of the opposite Doppler shifts across the structure
- in general, the Doppler shifts variations are not clearly matching the Hα integral line emission or the EUV AIA intensity behaviour
- the Doppler shift variations do not show any regular oscillatory behavior in time

1 – https://www.astro.sk/~choc/open/comp-s_lso_obs_prog_002/event_47_20140713/sdo_aia/

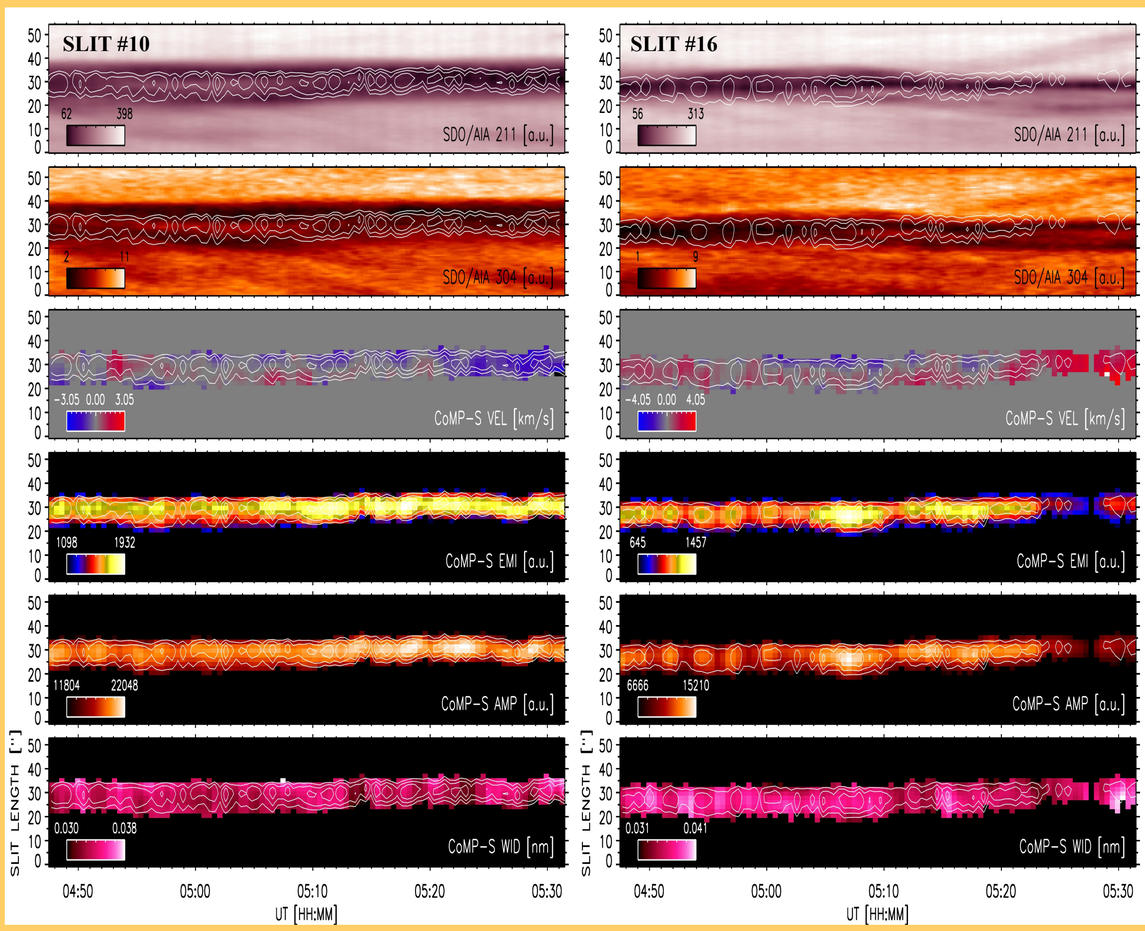

Fig. 3. The pseudo-slits #10 and #16: the time-space plots of the SDO/AIA 21.1 nm and 30.4 nm channel intensities (upper two panels) and the LSO/CoMP-S Hα line Gaussian fit parameters: EMI – the integral line emission, VEL – the Doppler shifts, AMP – the line amplitude, WID – the line width (bottom panels). White overlaying contours: behaviour of the Hα integral line emission.

Conclusions

Our results lead to the conclusion that the Doppler shifts of the particular target tornado-like structure cannot be interpreted as real cold plasma rotation around the vertical axis of the structure. However, the purely imaging SDO/AIA observations show clear illusive vortical motions in this tornado-like structure. This combination of results derived from the cool plasma spectroscopy and the SDIO/AIA imaging bears a resemblance to results presented already for a similar structure by Schmieder et al. (2017). We suggest that the "vortical illusion" (Panasenco et al., 2014) - a combination of the counter-streaming flows in the prominence threads - and possible radiative transfer effects in the cold plasma blobs in the prominence (Fig.4) - are causing the apparent rotational motion of this tornado-like structure.

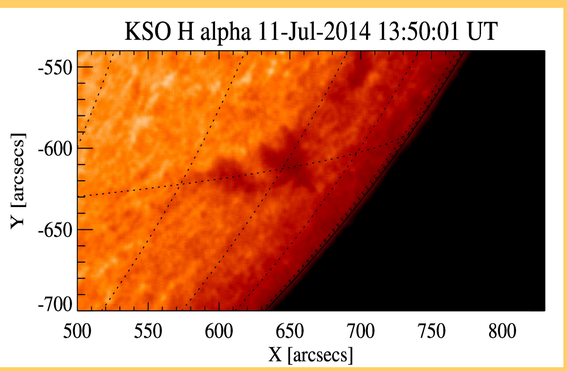

Fig. 4. The filament corresponding to the target tornado-like structure: the KSO Hα image, taken more than 1.5 days before the presented SDO/AIA imaging and the CoMP-S spectroscopic observations. showing the individual filament blobs located mostly in the E-W direction.

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