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


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 He II spectroscopy data acquired with the CoMP-S instrument (Lommicky Sit Strovity - LSO, AIAS, 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 the 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 vortex 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; Mgebhorsvili 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 a spurious effect. On the other hand, the cool material (T~10^4 K) 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 rotational 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 observations of a similar structure, whether it is a real tornado or we just observe illusive signatures of an apparent rotational motion.

LSO instrumentation & CoMP-S observations

Instrumentation:
- LSO instrumentation & CoMP-S observations

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 overcooking 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 2 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 representative pseudo-slits (#10 and #16) selected in the target structure for an illustrative display of the time-space cuts (Fig.3)

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 apparent vortical motions in the SDO/AIA intensity movies lead to a typical time-space behaviour of this tornado-like structure: variable/inclined tracks in the intensity variations (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

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

• July 13, 2014, south from AR 12110, above the SW limb: [7535°, 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)
• Ground-level motion in several parts of the structure (Fig.3, upper panels)
• SDO/AIA dark structure – CoMP-S Hα integral line emission masks: a clear coincidences of patterns

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 vortex motions in this tornado-like structure. This combination of results derived from the cool plasma spectroscopy and the SDO/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 - are causing the apparent rotational motion of this tornado-like structure.