# First Observation of a Transverse Vertical Oscillation During the Formation of a Hot Post-Flare Loop

*A&A 545, A129 (2012)*

**Rebecca White[1],** Erwin Verwichte[1] & Claire Foullon[1,2]

*R.S.White@warwick.ac.uk*

[1]Centre for Fusion, Space and Astrophysics, Department of Physics, University of Warwick, Coventry, CV4 7AL, UK

[2]College of Engineering, Mathematics and Physical Sciences, University of Exeter, Devon EX4 4QF, UK

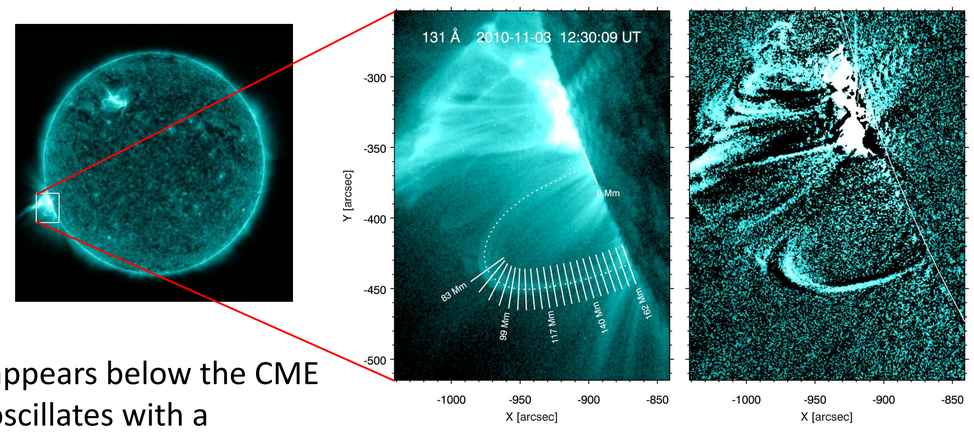
## Abstract

We present the first observation of a transverse oscillation in a hot coronal loop with the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory (SDO), following a linked coronal-flare mass-ejection event on the 3 November 2010. The oscillating coronal loop is observed off the east solar limb and exclusively in the 131 Å and 94 Å bandpasses, indicating a loop plasma of temperature in the range of 9 - 11 MK. Furthermore, the loop is not observed to cool into the other AIA channels, but just disappears from all bandpasses at the end of the oscillation.

This is the first observation of a transverse loop oscillation (TLO) observed exclusively in the hot coronal lines. The loop oscillation is vertically polarised and is dominated by a higher order harmonic mode. We conclude that the excitation mechanism of this 5 min period oscillation is directly connected with the reconnection processes that form the post flare loop, which differs from the blast wave excitation mechanism often proposed as the cause of cooler TLOs.

## SDO/AIA Observation: 3 November 2010

- CME/flare (C4.9 GOES) on the south east solar limb.
- Seen exclusively in 131 Å and 94 Å AIA bandpasses (between 9 - 11 MK).




- A hot loop appears below the CME ejecta and oscillates with a transverse motion that appears to be a higher order harmonic mode.

*Left: The hot loop is positioned below the CME ejecta. Cuts taken to analyse the oscillation are displayed. Right: a difference image highlighting the loop oscillation.*

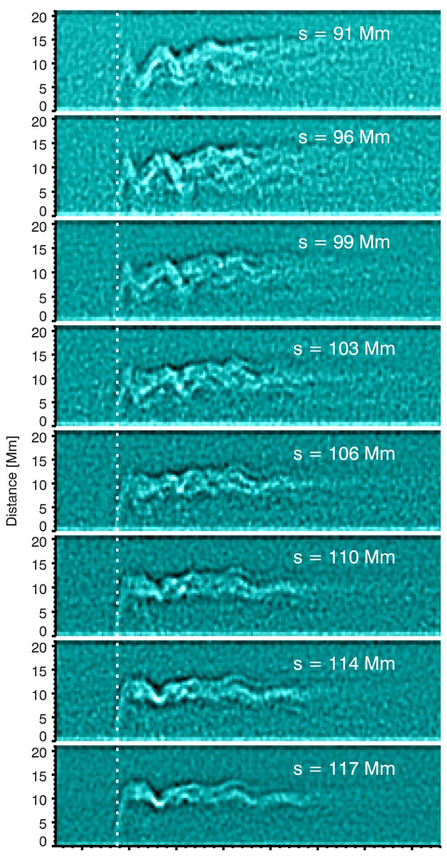
## Motivation

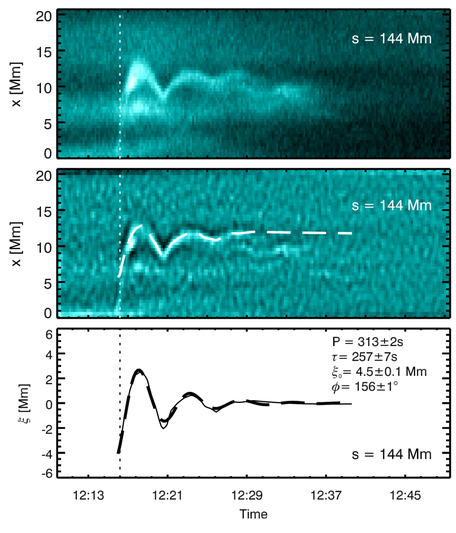
We present the first analysis of a higher harmonic vertical transverse loop oscillation (TLO) seen in a hot loop with SDO/AIA. This study is motivated by the following points:

- Oscillations detected in hot flare lines by instruments such as SUMER are interpreted as slow magneto-acoustic modes [*Wang et al. (2003), A&A, 406*]. Spatial observations of transverse loop oscillations have so far been limited to the cooler bandpasses (1-2 MK). [*E.g. Aschwanden et al. (2002), Sol. Phys., 206; White & Verwichte (2012), A&A, 537* ]
- Higher order harmonic and vertically polarised modes of coronal loop oscillations are rare. [*Verwichte et al. (2004) Sol. Phys., 223; De Moortel & Brady (2007), ApJ, 732; Van Doorsselaere et al. (2009), A&A, 508; Wang and Solanki (2004), A&A, 421*]
- TLOs can be used as a seismological tool, e.g. to determine the density stratification in coronal loops. [*Andries et al. (2005), A&A, 430; Dymova & Ruderman (2006), A&A, 457*]
- This observation raises questions about the excitation mechanism behind this hot post flare loop oscillation.

## Time Series Analysis

- Several cuts are taken at different positions along the loop.
- Displacement time profiles of the transverse oscillations are obtained for two strands in the loop and are fitted with a damped cosine curve.

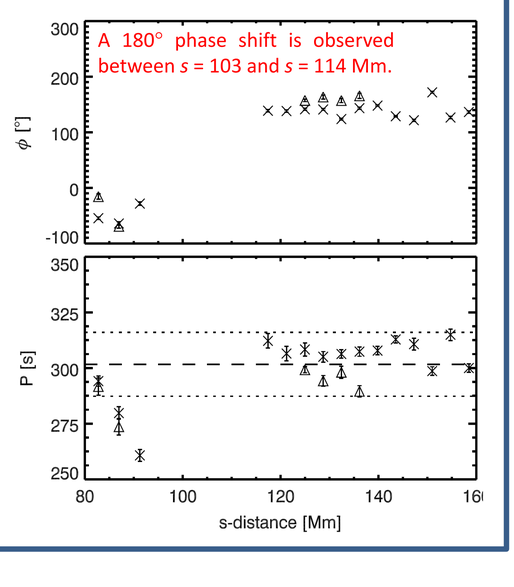



*Upper: time-distance image extracted from a cut at s = 144 Mm. Middle: a 2D Mexican hat wavelet transform has been applied to highlight the oscillations present. Lower: the de-trended time series was fitted with a damped cosine function.*

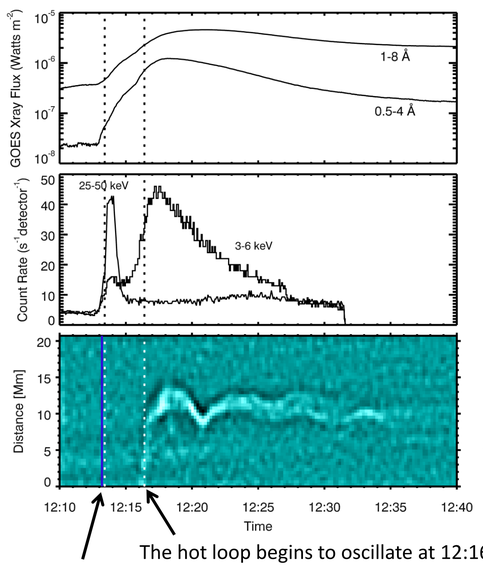
*Time-distance images extracted from cuts taken along the loop to analyse the oscillation. The cuts span the region where it is expected a node lies.*

- Time series analysis reveals a period of
- 302 ± 14 s (291 ± 9 s) and a damping time of 306 ± 43 s (487 ± 125 s) for the first (second) loop strand.
- A spatial phase shift along the loop of approximately 180° suggests that we observe a higher order harmonic.




*The phase (ϕ), and period (P) plotted as a function of s along the loop. The triangles show the results obtained for the second loop strand observed in six of the time-distance images.*

## Excitation of the Oscillation



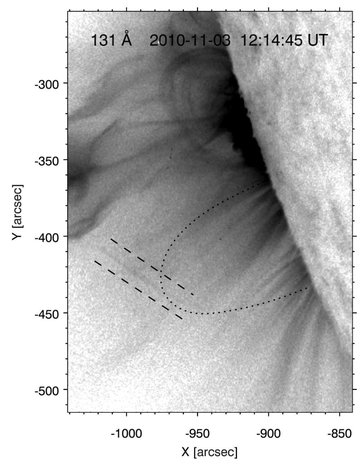

- The excitation occurs after the cool 171 Å loops where a blast wave is often the trigger.
- Numerical simulations of vertical modes have been performed, often with a pulse located directly beneath the loop top. [*Selwa et al. (2006), A&A, 454; Wasilijew & Murawski (2009), A&A, 498*]. However this hot loop appears to be excited from above.

*Upper: GOES (1–8 and 0.5–4 Å) soft X-ray flux. Middle: RHESSI (3–6 and 25–50 keV) X-ray flux. The 25–50 keV curve has been scaled by 0.25. Lower: an example time-distance cut of the 131 Å loop oscillation.*

The hot loop begins to oscillate at 12:16:33 UT.

Start of the CME eruption (12:13:21 UT) and excitation of the 171 Å TLOs (12:13:36 UT).

A strand originating from the direction of the CME towards the location of the loop just before the loop appears may indicate that the loop is directly formed as a result of flare reconnection processes that excite the loop from above the loop top.




*An AIA image showing a strand that appears to connect the CME with the region where the hot loop appears a short time later. The loop position is indicated by the dotted line and the strand is located between the two dashed lines.*

## Conclusions

- This is the first observation of a transverse loop oscillation in hot coronal lines.
- The loop oscillation is vertically polarised. This is supported by detected intensity variations and forward mode modelling of the oscillation.
- The loop is oscillating exclusively as a harmonic overtone (either n=2 or n=3) and the fundamental mode is suppressed.
- The excitation mechanism of this loop is different to that for the loops observed in the cooler bandpasses. ***We suggest that the formation and excitation is directly linked to the flare/CME reconnection processes.***