Investigation of shock nature of an EUV wave using a prominence activation

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Extended abstract

Associated with a large solar flare*1 occurred on Mar 7,2012, a wave-like coronal*2 disturbance(known as EUV waves) was observed. The EUV wave 'hit' a polar prominence*3 leading to its oscillation. We also found that the prominence strongly brightened when EUV wave 'pushed' it. Based on observational features, we interpreted the EUV wave*4 as fast mode MHD shock. By using the physical features of a fast mode MHD shock, we successfully explained prominence acceleration and compression and got a tool to diagnose physical quantities in the corona(coronal seismology) that are very difficult to directly observe.

*1: sudden enhancement of brightness in wide range of wavelength, *2: hot and rarefied outer atmosphere of the sun, *3: cool dense plasma cloud supported by magnetic force in the corona, *4:There are two main interpretations of the physical nature of EUV waves('MHD fast mode wave/shock' interpretation and 'non-wave' interpretations)

Observation

- X5.4 class flare started at 00:04UT and peaked at 00:24UT on March 7,2012(Fig1 a, b).
- The EUV wave propagated to the north with the speed of 500km/s(Fig2 a).
- A coronal disturbance was also observed by STEREO space craft(Fig2 b).
- Type Ⅱ Radio burst* was observed by HiRAS(Fig2 d).

⇒ We regard the observed EUV wave and coronal disturbance as a MHD fast mode shock front(Fig3).

- The EUV wave propagating northward 'hit' a polar prominence(Fig2 c).
- In hitting, the front of the prominence brightened(Fig4 b).
- The hitting launched oscillation of the prominence.

*which is known as a direct evidence of shock wave

Analysis and result

With the shock interpretation of the EUV wave, the initial velocity of the activated prominence represents the plasma velocity of a transmitted shock and the sudden brightness enhancement represents the compression of plasma in a dense prominence. In linear 1D perpendicular fast mode transmission case(Fig5), we have analytic expression how the wave transmits into prominence and how the compression rate is enhanced in the prominence.

$U_{p,t}/U_{c,i} = 2/(1+\sqrt{a})$,

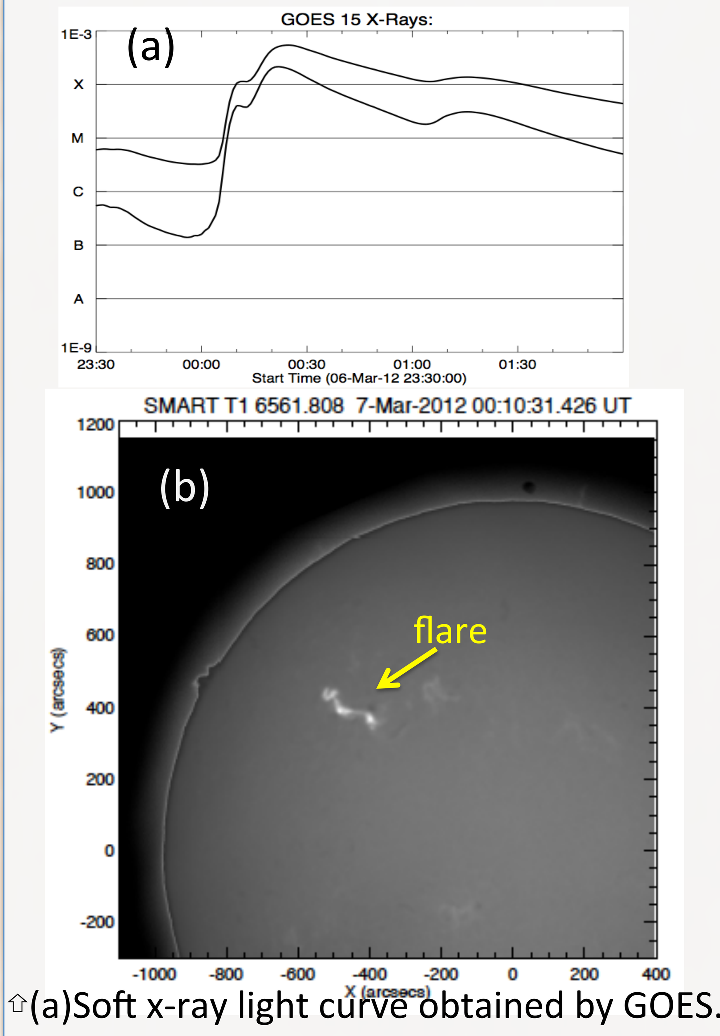
$(F_{p,t}-1)/(F_{c,i}-1) = 2\sqrt{a}/(1+\sqrt{a})$ where $a = \rho_p/\rho_c$ Applying observed quantities(V_c and U_p), we can estimate compression ratio of the EUV wave in the corona.

$F_{c,i} = V_c/(V_c-U_c) = 1.34 \sim 1.66$,assuming $a = 10 \sim 30$

Summary and conclusions

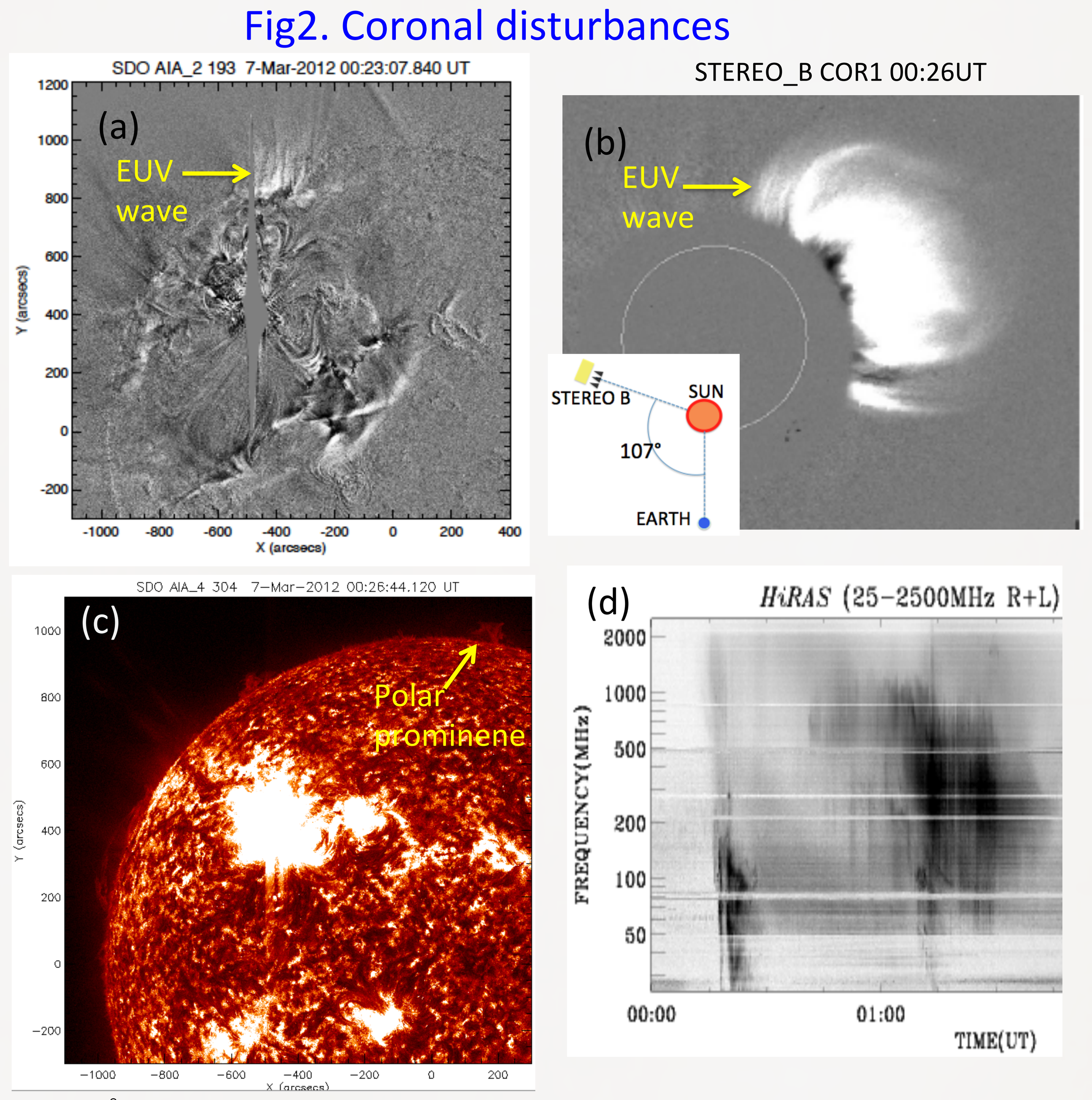
A globally propagated EUV wave associated with a large flare activated a polar prominence. Assuming the shock nature of the observed EUV wave, we could explain how the prominence was accelerated and compressed. With an assumed range of density gap between prominence and corona, we could evaluate the compression ratio of the EUV wave as a fast mode MHD shock. This work suggest that the prominence activation has a potential as a tool for shock wave investigation in the corona.

Fig1. SXR light curve & Hα image



⇧(a)Soft x-ray light curve obtained by GOES. The X5.4 flare peaked at 00:24UT.
(b)Hα image obtained by SMART/Hida Flaring active region and activated prominence are indicated by arrows.

Fig2. Coronal disturbances



⇧(a) 193Å difference image at 00:23UT obtained by SDO/AIA. The EUV wave is propagating to the north.
(b) White light scattered light difference-image at 00:26UT by STEREO B COR1. The Location of STERE B satellite on 7, March is also shown. The disturbance was co-spatial with the EUV wave front.
(c) 304Å image at 00:26UT obtained by SDO/AIA. Activated prominence can also be seen.
(d) Radio spectrum showing Type Ⅱ radio burst from 00:19UT by HiRAS.

Fig3. Schematic figure of observed coronal disturbances

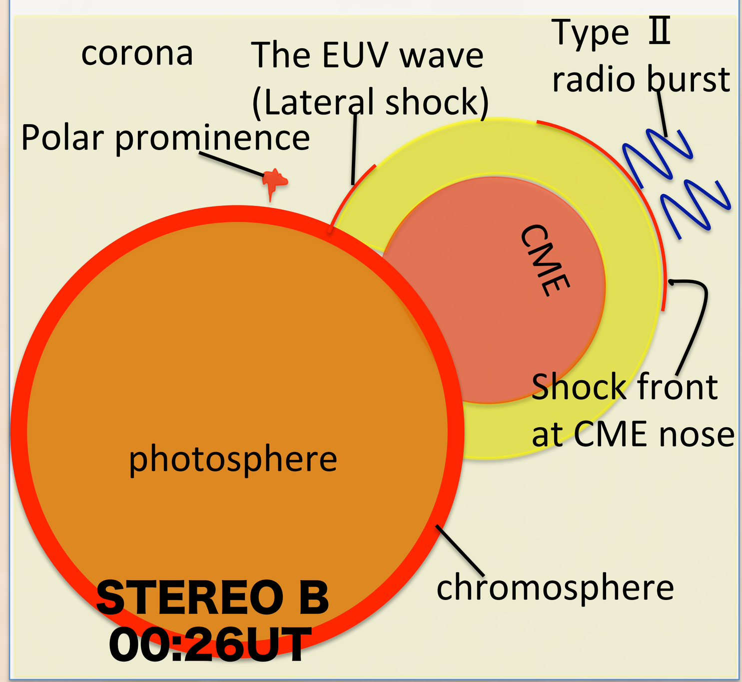
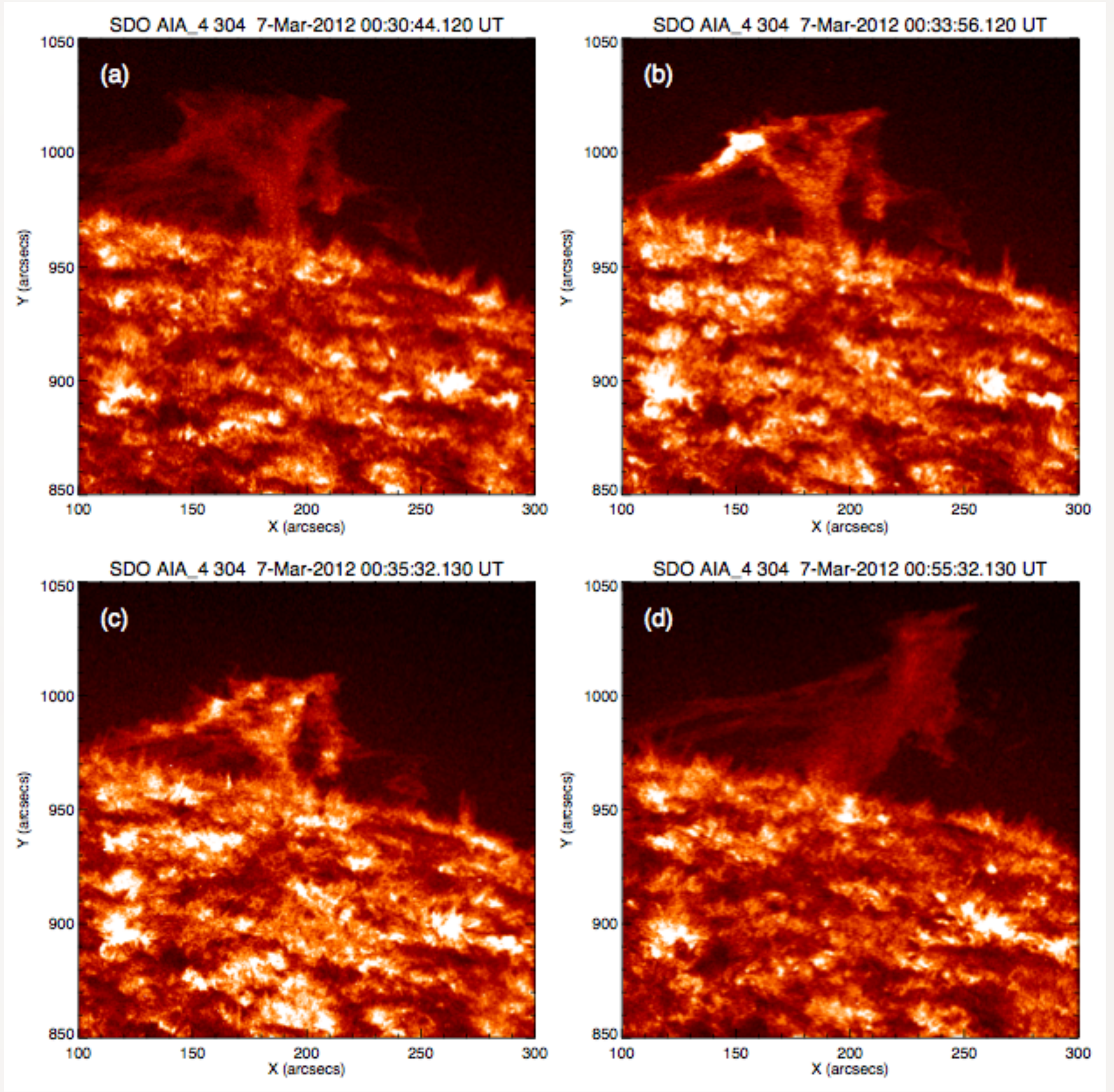
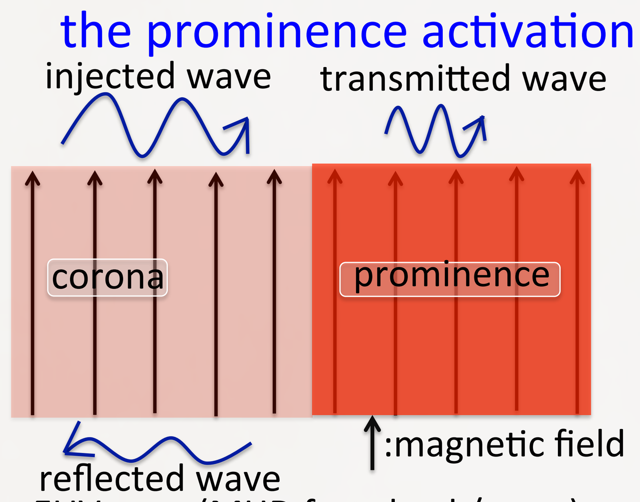


Fig4. Close-up images of prominence activation



⇧304Å images obtained by SDO/AIA
(a) 00:30UT just before hit by the EUV wave
(b) 00:33UT start to be pushed and brightened
(c) 00:35UT bright part propagated through the prominence
(d) 00:55UT after EUV wave passed, swung to the right

Fig5. Simplified model of the prominence activation



⇧The EUV wave(MHD fast shock/wave) transmits from ambient corona into dense prominence resulting in the prominence acceleration and compression.

- Model physical quantities

ρ_c,ρ_p = initial plasma density
V_c,V_p = wave propagation velocity
$U_{c,i},U_{p,t}$ = plasma velocities of EUV wave
$F_{c,i},F_{p,t}$ = compression ratio of EUV wave
(subscript: c = corona, p = prominence, i = injected, t= transmitted)

References

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- Chen, P. F., & Wu, Y. 2011, ApJ, 732,L20
- Patsourakos, S., & Vourlidas, A. 2009, ApJ, 700, L182