Linking Various Signatures of the February 15, 2011 Solar Flare

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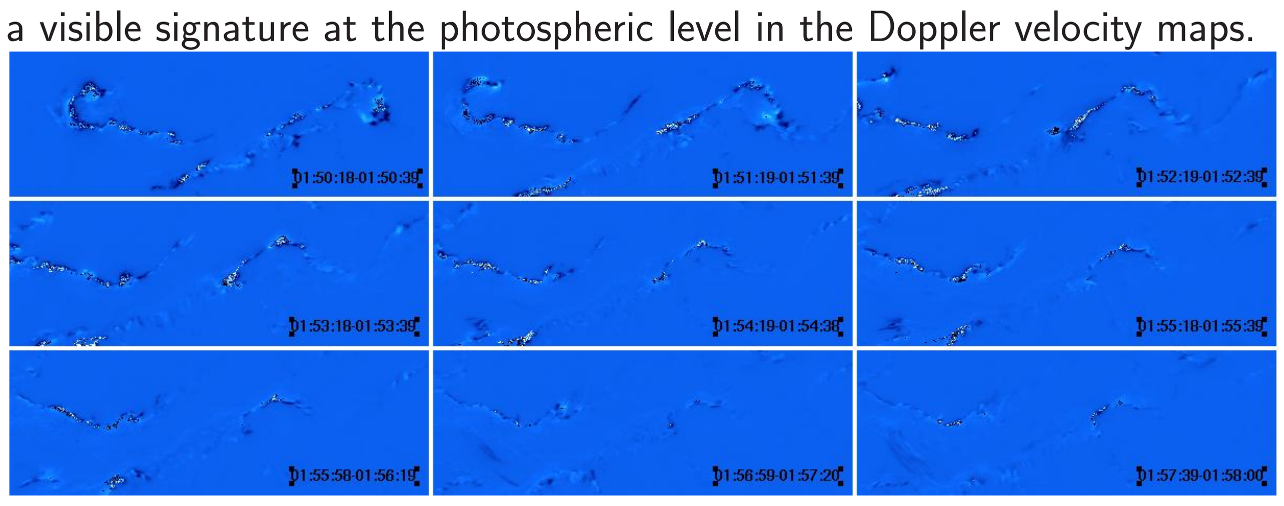
Abstract

The first sun quake of SC24 was reported by Kosovichev (2011), followed by Martinez-Oliveros et al.(2012) and Zharkov et al.(2012) and it was triggered by the February 15, 2011 X2.2-type solar flare (01:45–01:56 UT). This was a very interesting flare accompanied by many phenomena, namely a white light signature, a full halo coronal mass ejection (CME), a microwave burst, an EIT wave and an interplanetary CME (ICME). The ICME arrived at the Earth on February 18 and it produced a minor geomagnetic storm (Dst=-30 nT). In this work we focus on the seismic emission properties and CME kinematics. One of its aims is to predict the geomagnetic storm strength by using a logistic regression model based on solar and interplanetary variables (Srivasta, 2006). We are also investigating any possible connection among the different phenomena mentioned above.

The first sun quake of SC24 which was triggered by the February 15, 2011 X2.2-type solar flare (01:45–01:56 UT) was reported by Kosovichev (2011), followed by Martinez-Oliveros et al. (2012) and Zharkov et al. (2012). This flare was a very interesting one accompanied by many phenomena, namely a white light signature, a full halo coronal mass ejection (CME), a microwave burst, an EIT wave and an interplanetary CME (ICME). The ICME arrived at the Earth on February 18 and produced a minor geomagnetic storm (Dst -30 nT). In this work, we focus on the seismic emission properties of the flare and the kinematics of the associated CME. One of the main aims of this study is to predict the geomagnetic storm strength by using a logistic regression model based on solar and interplanetary parameters of this event (Srivastava, 2006). We also investigate possible connections, if any, among the different phenomena mentioned above.

Flare Times: 01:44–01:56–02:06 UT

Above the $\beta\gamma$ AR NOOA 11158 situated at S21W21 there was an X2.2-type solar flare, very sudden and short. It showed a two ribbon evolution (See Figure 1 below) besides the magnetic neutral line. The flare has a visible signature at the photospheric level in the Doppler velocity maps.



SunQuake Times: 01:44(begin); 01:50(max); 01:58(end)

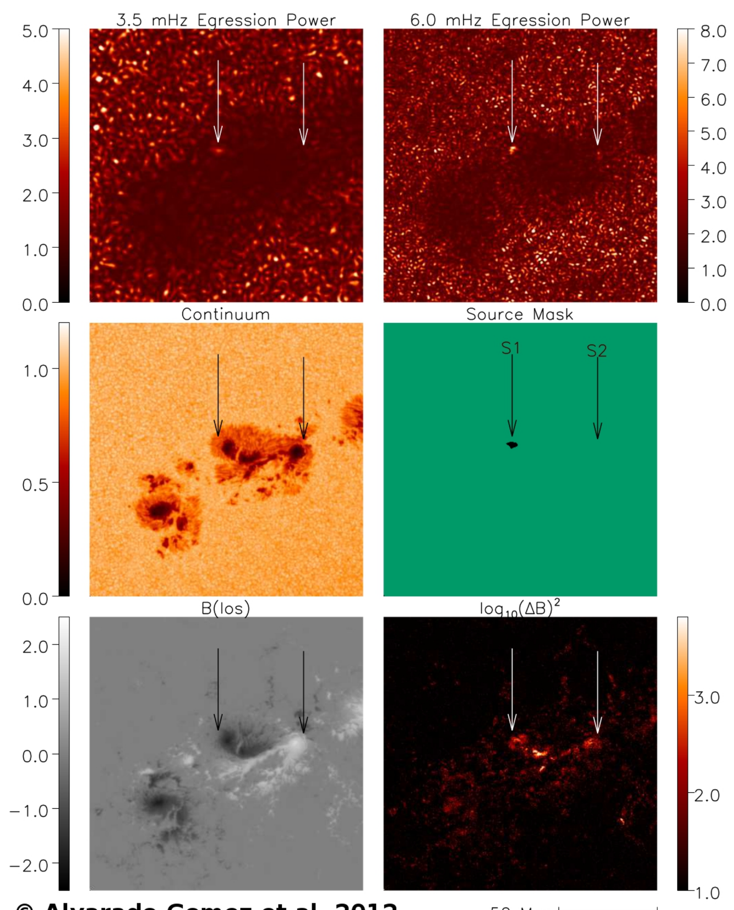


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Figure 2 shows a composite image of the active region with the seismic emission at 3.5 and 6 mHz egression power maps on the first row, an intensity continuum map and a threshold mask of the sources regions on the second row; last row shows a pre flare line-of-sight magnetic field in kG (left frame) and base-ten logarithm of the mean square line-of-sight magnetic variation in the 2.5-4.5 mHz spectrum during the impulsive phase of the flare (right frame) (See Alvarado-Gomez et al. 2012 for more details).

This sunquake is one of the few known sunquakes to date to have a visible front (almost circular) wave (Kosovichev, 2011). The seismic emission is very well temporally and spatially correlated with the magnetic transient, the white light signature and the Doppler velocity depletion at the photosphere.

CME evolution

Following this flare at 02:24:05 there was a Halo CME registered by LASCO/SOHO. Its linear speed was 669 km/s, the 2nd-order Speed at final height was 508 km/s and 2nd-order Speed at 20 Rs of 471 km/s.
Below is the source region of this CME observed by STEREO/EUVI images.

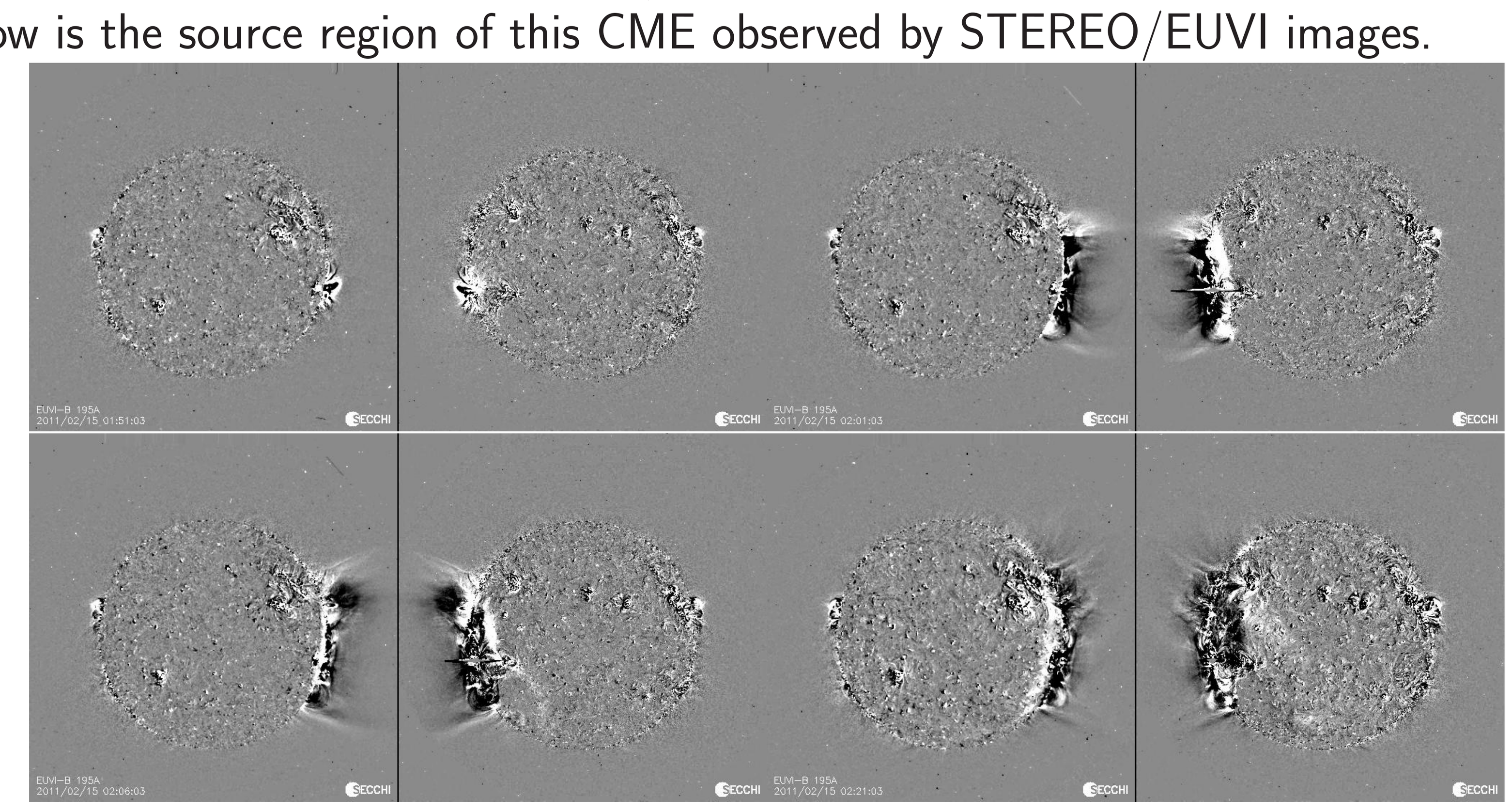


Figure 3: running differences of STEREO – EUVI 195 (right - A, left - B) showing the wave and dimming. Specific times shown in each frame.

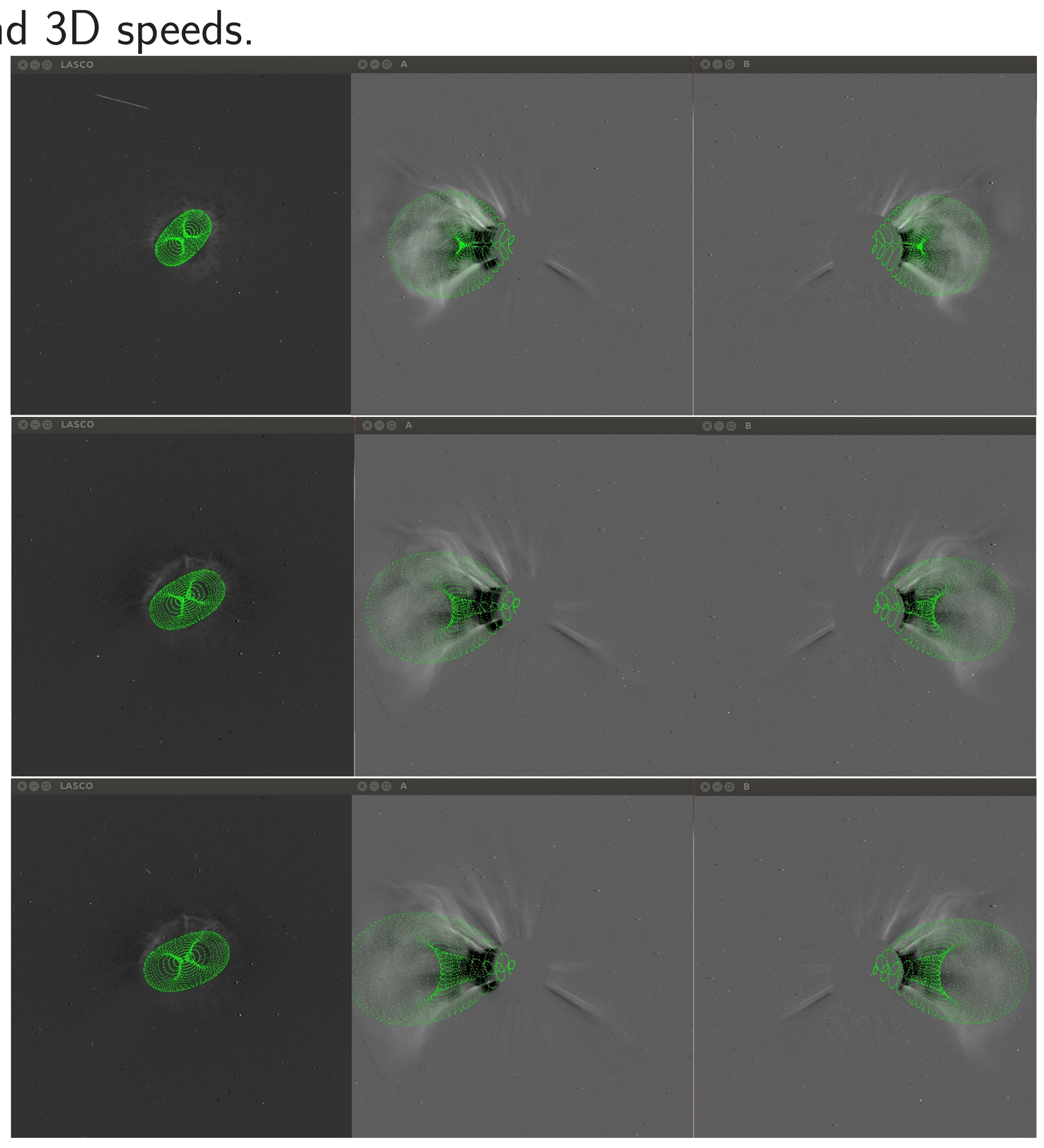
Regression Modelling (Srivastava, 2006)

In order to estimate the probability of the CME to be followed by a geomagnetic storm we have applied the following formula: $\Pi_i = \frac{1}{1+\exp(-Z_i)}$

$Z_i = -10.06 + 7.25 \times 10^{-03} \times V_{CME} + 0.23 \times Lat + 3.93 \times 10^{-02} \times Lon - 4.03 \times 10^{-02} \times (NL\ orientation)+$
$4.88 \times 10^{-03} \times (Flare\ impact\ parameter) \Rightarrow \Pi = 10\ \%$

Forward Modelling

Forward Modelling applied to COR2 images in order to derive the direction of propagation and 3D speeds.



Date	Time (COR2)	long	lat	Tilt angle	height	ratio	Half angle	speed	Comments
15-02-2011	03:54	2	-8	43	11.64	0.37	34		Cme has a deformed shape. FH C2 not fitted well.
15.02.2011	04:39	3	-9	27	14	0.37	34	608	Cme deflected towards the equator
15.02.2011	04:54	3	-9	19	15.36	0.37	34	1051	

ICME Parameters

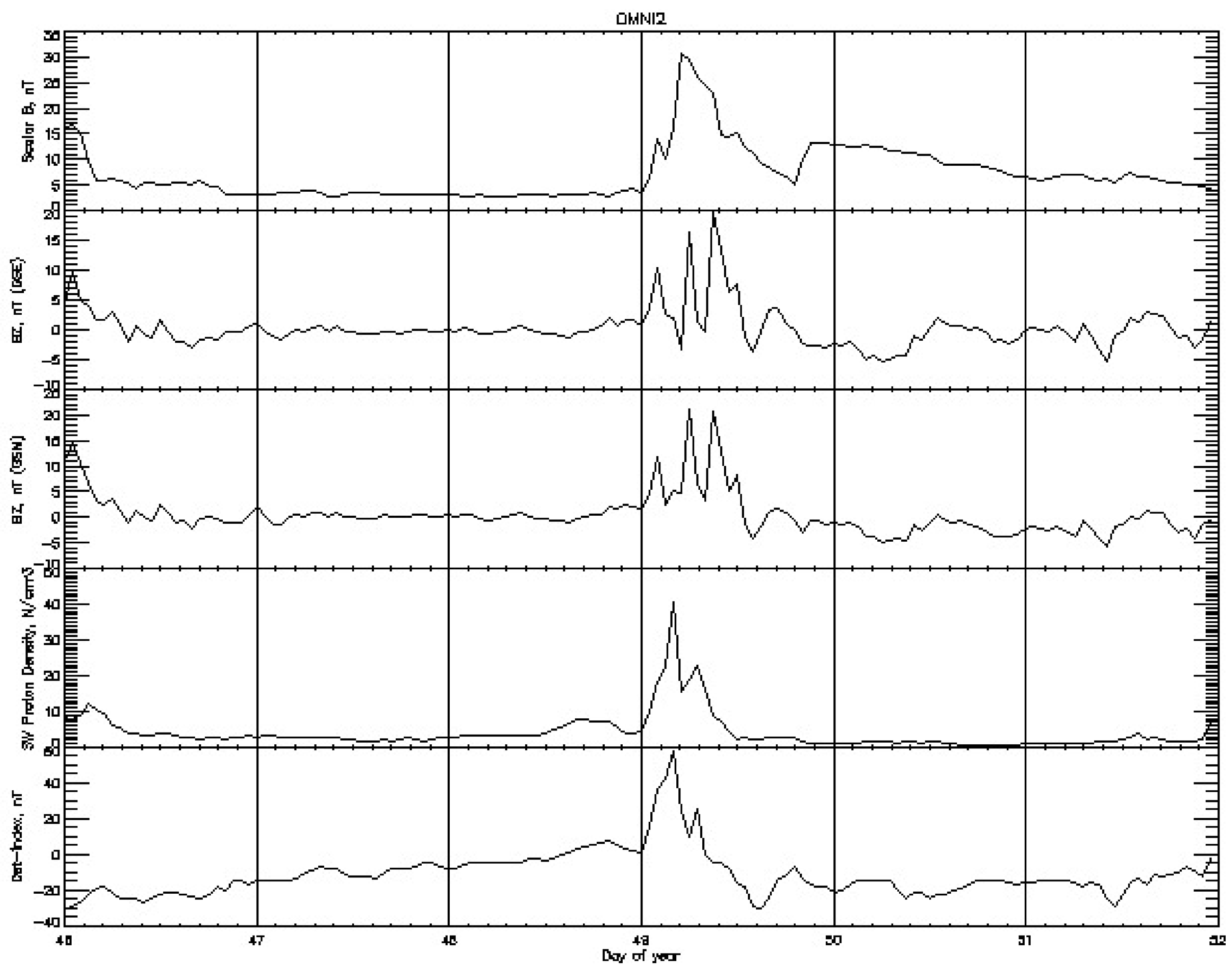


Figure 5 shows specific geomagnetic storms parameters: Scalar B_z, B_z, SW proton density and DST. This storm is characterised by a less common increase in the Dst values preceding the minimum registered (-30) in February 18 at 15:00 UT.

Summary

We have shown this event to be a complex one with many signatures in various wavelengths that are very well correlated, both spatially and temporally. However, we have found there is no direct link between seismic emission and occurrence of magnetic storms.
By using the derived solar parameters (location of the source region, speeds etc.) we got a very low probability of a major geomagnetic (i.e. Dst ¡ -150 nT) which agrees with the geomagnetic observations.
Future work should include a statistical comprehensive study of seismically active flares accompanied by CMEs and followed by geomagnetic storms.

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