Chromospheric impact of an exploding solar granule

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**Outlook**

QUEST (Q-quiet sun Event Statistics) is a 5 year Junior research group project at the Kiepenheuer Institute for Solar Physics from May 2018 and co-financed through the Spanish “جون دورى” program.

The aim is to systematically study the quiet-sun using multi-wavelength spectropolarimetric data from various telescopes. Such events as described in this paper as well as flux cancellation, convective collapse events and so on will be searched for and characterized from the photosphere to the transition region.

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**Exploding granule event**

A small bright granule (area of ∼ 3.35 arcsec², contourd in red) is seen in the Hinode SP continuum map two and a half minutes into the co-occurring sequence. The granule explodes by expanding with a rate of about ∼ 0.77 arcsec² per minute, and then develops a dark core before splitting into several fragments, finally reaching a ring shaped form with an overall size of about 14 arcsec² at T ≈ 19 min. The morphological evolution of our exploding granule in the photosphere is consistent with Hir dealer et al. (1999).

**Hinode** (Tsuneta et al. 2008)

- Spectropolarimeter (SP)
  - bidimensional full Stokes 630 nm slit spectra
  - spatial sampling of ∼ 0.32")
  - region of about 8 × 1 arcsec²
  - sampling of 21.5 arcsec² and a cadence of ∼ 70 s.

**Additional Hinode Broadband Filter Imagery and Narrowband Filter Imagery** Filtergrams were used to align to IRS slitline images. The images were beforere bidimensional spatial. To find co-temporal data, the middle of exposure times for filtergrams and the time of the central slit position of the Hinode SP map were chosen.

**“Squeezing” of magnetic elements**

There is a group of mixed polarity strong magnetic elements (∼ 500 G) that occupies the intergranular lanes in the vicinity of the exploding granule. After the exploding phase the elements are arranged in a circle around the granule, outlining its border and tracing the same ring-like pattern seen in the Hinode SP continuum map. The Flux Continuum Correlation Tracking (FLCT) code by Fisher & Welch 2008 to obtain two-dimensional (2D) velocity fields inferred from the Hinode SP continuum maps.

At T ≈ 5-7 min the magnetic elements at the edge of the exploding granule at around x = 2" and y = 5" (Figure on the right, position A) experience strong horizontal velocities from both sides; the interior of the exploding granule and the surrounding granules. This gives the impression of magnetic elements being squeezed by the opposing flows. This is confirmed by the magnetic flux density evolution. The contours of the magnetic flux density maps show a stretching out of the magnetic elements, leading to a more elongated shape (compare, for example, panel one at T = 8.5 min and panel three at T = 13.3 min in the middle row of the Figure on the right) and a separation of the magnetic flux elements. This is accompanied by a decrease in the total magnetic field strength as seen in the last row and therefore not due to a change of the inclination angle tilting the magnetic field.

**Triggering of oscillation**

We follow the time development of the (high) photospheric line of sight velocity obtained from fit to the IRS Fe I 2797.0 Å line and the IRS Mg II k peak intensity, a good indicator of the coronal chromospheric temperature according to Pereira et al. (2013)) in a spatial section along the IRS slit. In both diagnostics, a similar oscillatory pattern is seen, although out of phase, and starting at around T = 10 min for the high photosphere and around 12 min for the corona for the last few minutes and located area N of the magnetic element location observed in the Hinode SP magnetic flux density maps. The oscillatory pattern appears one to two minutes after the presumably described squeezing of the magnetic elements at the IRS slit location.

**Wavelet analysis**

We apply a wavelet analysis on various parameters derived from the IRS slit spectra using the code provided by C. Torrence and G. Compo (http://atoc.colorado.edu/research/wavelets/) and using the default Market wavelet. In the Figure to the right we show the results for the velocity and intensity fluctuations in 1.) the photospheric Fe I 2797.0 Å line, 2.) the Mg II h, l minimum, 3.) the Mg II k peak sampling the low to mid chromosphere (Pereira et al. 2013), and 4.) the Mg II k sampling the high chromosphere (Leenaarts et al. 2013).

The wavelet analysis shows a power peak in both the velocity and intensity fluctuations of the photosphere to mid-chromosphere diagnostics, with a delay increasing with height between the maximum power. The maximum power is located at a period of between 2 and 3 minutes including also larger periods in the mid-chromosphere of up to 5 to 6 minutes. The high chromospheric signatures, as seen with the Mg II k amplitude (rightmost panel), show no power and only a weak modulation in the velocity power. As seen in the left panel mapping the amplitude in intensity, there is an increase visible in the amplitude which implies a change of the transition region height (Pereira et al. 2013).

This could signify dissipation of the shock wave energy and local heating of the high chromosphere. Upward-propagating shock fronts are common in quiet Sun chromosphere, both in observations (Beck et al. 2009, Carlsson & Stein 2010, Wedemeyer et al. 2004). We do not find a significant excess emission co-spatial with the chromospheric emission in the C CI 3355 Å line of IRS, which is consistent with our finding that dissipation happens at the middle chromosphere.

**Conclusion**

A magnetic element at the edge of an exploding granule is squeezed by opposing horizontal flow, resulting in an elongation of the isocenturs in magnetic flux as seen with the Hinode SP, with a chromospheric response consequently being triggered and observed in the IRS spectra. Signatures of energy deposition in the middle chromosphere are seen through a wavelet analysis of different spectral features in the Mg ii k & l spectra.

Our finding is consistent with an up-down-propagating shock front triggered by the exploding granule.

**Acknowledgements**

CEC has been funded by the DFG project Fu 2058/1-3. NSB acknowledges financial support to the European Union of the Lobitos-Chica project. This project has received funding from the Spanish Ministry of Economy and Competitiveness through project AYA2014-58614-R.

Hinode is a Japanese mission developed and launched by ISAS/JAXA, collaborating with NAOJ as a domestic partner, NASA and STFC (UK) as international partners.

IRIS is a NASA small explorer mission developed and operated by LMSAL, with mission operations executed at NASA Ames Research Center and major contributions to data processing funded by ESA and the Norwegian Space Centre.

**References**


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**Figure CAPTION:**

Left: right panel: a) the Mg II line C flux map overlaid with the continuum image and horizontal flows in the Figure above. The two vertical white lines delimit the position of the IRS slit in use. Two dashed red horizontal lines and a solid red line mark a region of interest. Panels b) and c) are time-space images derived from spectra recorded by the continuum flux in each one. Panel b) shows a core one-dimensional (1D) velocity profile of the Mg II line at 2799 Å, where dialogues are plotted (red) using the code WSOG (Pereira 2013). Panel c) the intensity of the Mg II k peak (in data units) obtained by the ion, jet, map, region, jk, and one is plotted. The red horizontal lines indicate the same area as in panel a). The solid vertical line in panel c indicates the time of the map (panel a) and panel c) shows a spectrum at that time (solid black) and a local equivalent (dashed). The dashed vertical lines denote the average position of the Mg II k peak and its standard error.

The right panel demonstrates the temporal evolution of the IRS slit spectra at the same slit position, but the horizontal line is panel a) with the time of panel a) indicated again with lines in cyan.

**Figure 4:**

Exploding granule event.

**Figure 5:**

Hinode SP continuum maps with filled contours of the magnetic elements sampled with INFIR-2 dimensions obtained with the standard inversion parameters from http://www.has drivers.edu/irsa/.
Connecting magnetic field and velocity dynamics in the photosphere with the energetic response in the chromosphere are crucial for our understanding of the physical processes that couple these different regimes in the solar atmosphere. We analyze photospheric full Stokes polarimetric data in the Fe\textsubscript{i} 630 nm doublet as well as narrowband filter magnetograms in Na\textsubscript{i} D and broadband images in Ca\textsubscript{ii} H from the Hinode satellite. Additional co-temporal and co-spatial NUV and FUV spectra were obtained with the IRIS satellite. We follow the process of a rapidly expanding granule in the photosphere interacting with the surrounding magnetic elements. The magnetic elements are squeezed by the convective flows of the granular motions and are compressed. In reaction to the squeezing, we detect a chromospheric intensity and velocity oscillation pulse with a period in the range of 2 to 3 min. Using a wavelet analysis on the chromospheric emission features such as Mg\textsubscript{i} k\textsubscript{2}v and Mg\textsubscript{i} k3 we identify the signal as an upward traveling hot shock front which dissipates in the chromosphere.