X-ray network emission and photospheric vortices: observations with Hinode and SoHO

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Quiet Sun: How does the photospheric flows contribute to the x-ray emission in the low corona?

- Reminder: Balltacking from Potts et al. (2004), (2007) and (Attie et al. 2009)
- Hinode-SoHO’s observations and co-alignment
- Photospheric velocity fields, magnetic field (LOS), and x-ray emission
- Discussion on models, space weather and “all-clear forecasting”
Reminder : Balltracking
(Potts et al., 2004)
Balltracking the photospheric flows

$m \dot{v} = \sum_i f_i + mg - \alpha v$

$f_i$ : Archimede-like force, function of the penetration distance

Balltracking (Potts et al., 2004)

Applied to SoHO/MDI:
High-Res continuum images

(Attie et al., 2009)

Applied to FG-SOT/Hinode:
Blue continuum, G-band.
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**(Attie et al., 2009)**

Applied to FG-SOT/Hinode:
Blue continuum, G-band.
First application on Hinode observations (Attie et al., 2009)

10 April 2007

- Cadence: 2 minutes
- 1 hour of continuous observation

07 November 2007

- Cadence: 3 minutes
- 5 hours continuous observations
Distribution of the velocity field (calibrated)

**Quiet Sun - 1 Hour dataset**
- **Multiple cadences**
- **Average over 45 Minutes**
- **FWHM smoothing = 3 Mm - 3.8”** Above thresholds from Rieutord et al. (2001)

FG-FOV, over 45 minutes, at 3-min-cadence
- 200< Modal and Mean velocities < 300 m/s

Same as
- Krijger et al. (2002) LCT
- Potts et al. (2004) Balltracking
- Smoothing-dependent

Reminder: balltracking
10th April 2007, snapshot (over 30 min)

Reminder: balltracking

Attie et al. (2009)
07th November 2007, snapshot (over 45 min)

Attie et al. (2009)
Photospheric vortex flows at the supergranular junctions

Typical size: 15-20 Mm

07th November 2007, snapshot (over 45 min)

Attie et al. (2009)
Observations and Co-alignment
## Observations on 09/26/2008

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Lower Corona</strong></td>
<td>XRT/Hinode (X-rays images)</td>
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<td><strong>Photosphere</strong></td>
<td>FG/SOT-BFI (Hinode) : Granulation in blue continuum</td>
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<td></td>
<td>FG/SOT-NFI : Na I stokes V/I : uncalibrated (bubble problem)</td>
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<td>MDI : High Res (1”~0.7Mm ) continuum images, magnetograms of LOS B.</td>
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Co-alignment using the photospheric network lanes of both MDI and FG/SOT (Hinode)

- Lanes of same width.
- Alignment on lanes and common junctions.
How “reliable” are these lanes?

Places where the LOS magnetic field is swept out (with MDI magnetograms, or Ca II in FG-SOT)
XRT

- Quiet Sun
- Disc center, over 4 hours
- FOV : ~384x384 arcsec$^2$ (268x268 Mm$^2$)
- pixel size : ~1 arcsec
Co-alignment between XRT and MDI

- Still under development.
- Need well visible loops and MDI footpoints.
- For now: +/- 3 arcsec alignment
- Probably will need TRACE + full disk MDI.

Initial misalignment

Attempt of co-alignment on footpoints of x-ray loops

Green-blue contours: MDI LOS B (+/- 180G)

Average over 4 hours
Co-alignment between XRT and MDI

Observations and Co-alignment

Average over 4 hours

Average over 4 hours (FG/SOT FOV)

Difficult to discriminate from bright broad footpoints or loops, either in average image or time series.

Green-blue contours: MDI LOS B
Photospheric vortices and X-ray network emission
Photopheric vortices and X-ray network emission

- XRT
- Network Lanes (FG/SOT)
- Average over 4 hours
Photopheric vortices and X-ray network emission

- XRT
- Network Lanes (FG/SOT)
- Average over 4 hours

![Graph showing XRT network emission intensity over 4 hours](image-url)
Photpheric vortices and X-ray network emission

- XRT
- Network Lanes (FG/SOT)
- Average over 4 hours

Most “important” network emission at the supergranular junctions
Photpheric vortices and X-ray network emission

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Most “important” network emission at the supergranular junctions
Photpheric vortices and X-ray network emission

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- MDI contours (LOS B at +/- 140 G)

⇒ Most “important” network emission at the supergranular junctions
Photopheric vortices and X-ray network emission

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MDI contours (LOS B at +/- 140 G)
Photpheric vortices and X-ray network emission

- XRT
- Network Lanes (FG/SOT)
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• MDI contours (LOS B at +/- 140 G)

➡ Most “important” network emission at the supergranular junctions
Photpheric vortices and X-ray network emission

• XRT
• Network Lanes (FG/SOT)
• Average over 4 hours

Most “important” network emission at the supergranular junctions

Light curves over frame A and B

Circulation over SG. junction A and internetwork
Photopheric vortices and X-ray network emission

Frame A

Vortices

Frame B

Twisted flows
Photopheric vortices and X-ray network emission

Frame A

Background: XRT
Green-yellow contours: NFI stokes V/I

Frame B

Background: XRT
Green-yellow contours: NFI stokes V/I

Reconnection? (ask author for movie)
Photopheric vortices and X-ray network emission

Frame A
Background: XRT
Green-yellow contours: NFI stokes V/I

Frame B
Background: XRT
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Reconnection? (ask author for movie)
Discussion about the Quiet Sun (1)
Discussion about the Quiet Sun (1)

- SG junctions:
  - Sites of both transient “relatively” strong X-ray emission, and more permanent X-ray brightening
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• **SG junctions:**
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• **Magnetic field and SG junctions:**
  ‣ mixed polarities “encounters” in the vortices or in the twisted lanes during X-ray outburst
  ‣ Absence of clustered field in SG junctions or network: no significative X-ray emission
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• Open question about the vortices :
  ‣ Shearing of bipolar fields induced near the neutral line, by Amari et al. (2009)
  ‣ Induced magnetic stress, energy build up triggering the transient and permanent X-ray strong emissions, as in active regions (Machado et al., 1988, Moore et al., 1999)?
Discussion about the Quiet Sun (2)

- Quiet Sun regions are dominant during low solar cycle.
- Scaling law? Similitudes between Quiet Sun transient X-ray emission and flares in AR must be investigated.
- Photospheric motions are a new observable for real time monitoring of solar activity. Space weather forecasting could use it.
- Forecasting the “all clear” (Nasa workshop): Are the photospheric twisted motions a necessary condition (sufficient or not) to trigger eruptive events?
References

  “Quiet Sun mini-coronal mass ejections activated by supergranular flows”

  “Evidence of photospheric vortex flows at supergranular junctions observed by FG/SOT (Hinode)”

  “Automatic Recognition and Characterisation of Supergranular Cells from Photospheric Velocity Fields”

  “Balltracking : An highly efficient method for tracking flow fields”

  “Photospheric flows measured with Trace”

  “Are granules good tracers of solar surface velocity fields”

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  “A Twisted Flux Rope Model for Coronal Mass Ejections and Two-Ribbon Flares”

  “On Heating the Sun’s Corona by Magnetic Explosions: Feasibility in Active Regions and Prospects for Quiet Regions and Coronal Holes”

  “Vortex flow in the solar photosphere”

  “The observed characteristics of flare energy release. I - Magnetic structure at the energy release site”