The quiet Sun small-scale activity

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It has been shown (Falconer et al. 2003, ApJ 593, 549) that the luminosity of the quiet corona is proportional to the length of the magnetic "coastline" along the network, meaning that the heating of the large scale corona could be mainly driven by the small-scale magnetic activity at the edges of the network magnetic flux concentrations. This is the location where two important classes of transient events are mainly observed: explosive events (EEs) (Teriaca et al. 2004, A&A 427, 1065), and spicules (Beckers 1968, Sol. Phys. 3, 367).

EEs are observed in lines formed between 5×10^4 K and 7×10^5 K (i.e., within the solar Transition Region (TR)). First discovered by Brueckner and Bartoe (1983, ApJ 272, 329), they are commonly observed in quiet Sun and Coronal Hole areas as strongly non-Gaussian line profiles implying high velocity flows. EEs are characterized by a spatial scale of about 1800 km and average lifetime around 60 s. In the majority of the cases they also show a substantial increase of the integrated radiance with respect to the pre-event value so that they can be identified as small and short–lived TR brightenings in a sequence of images. The association with episodes of photospheric magnetic flux cancellation (Dere et al. 1991, J.G.R. 96, 9399; Chae et al. 1998, ApJ 497, L109) suggests they are the result of magnetic reconnection. Petschek-type reconnection in the TR may explain the observations (Innes et al. 1997, Nature 386, 811). This is also supported by the finding that around half of the EEs first appear in lines formed around 1.5×10^5 K (Mendoza-Torres et al. 2004, A&A 431, 399).

Magnetic reconnection is believed to be a suitable mechanism for extracting the energy stored into the magnetic field generated in the interior of the Sun, meaning that EEs could be locations of energy dissipation.

However, attempts to estimate the energy associated to EEs seem to indicate that not enough energy is associated with these events. Moses and Cook (1994, Spa. Sci. Rev. 70, 81) and Teriaca et al. 2002 (A&A 392, 309) report that there is no evidence of EEs in the $T \geq 1$ MK corona. Moreover, Winebarger et al (2002, ApJ 565, 1298) and Teriaca et al. (2004, A&A 427, 1065) show that also the kinetic energy and enthalpy flows associated to EEs are too small for being relevant. This does not exclude that energy could still be transported away from the reconnection site by waves generated by the supersonic flows, and dissipated over large volumes of plasma. Moreover, very high temperatures (several MK) could be reached at the reconnection site and large part of the energy could be dissipated as accelerated particles. These features are currently out of the sensitivity of the present-day instruments.

Spicules are elongated structures extending above the solar limb up to around 15 Mm (Withbroe 1983, ApJ, 267, 825; Cook et al. 1984, Adv. Space Res., 4, 59), showing variations indicative of apparent motions around 30 km s^{-1} (Wilhelm 2000, A&A 360, 351). This author suggested that EEs may be closely related to spicules, outlining a mechanism where EEs could be the first stage of a sequence of events leading to the formation of a spicule. Recently, Teriaca et al. (2004, A&A 427, 1065) have shown that EEs are often associated to larger scale flow patters that are prevalently blue–shifted and that the number and the area covered by such flow patterns is compatible with the area and occurrence rate of spicules.

On the other hand, De Pontieu et al. (2004, Nat. 430, 536) suggest that spicules may arise from chromospheric shocks powered by the leakage of solar global acoustic oscillations (p-modes) into the corona along inclined magnetic flux tubes. Whether such shocks are also able to produce EEs is still to be verified. Finally, it is interesting to note that Ning et al.

(2004, A&A 419, 1141) report that EEs occurring in bursts show 3 – 5 min. periodicity, suggesting a relations with oscillations. We could hypothesize a scenario where EEs and spicules are related phenomena occurring at the edge of the network concentrations and playing a relevant role in heating the corona and, within coronal holes, accelerating the solar wind.

More in details we hope to address the following points:

- Whether a relation between EEs/brightenings and spicules exists and, if so, to determine the temporal sequence of the events.
- The behaviour/topology of the magnetic field associated to such events.
- Is there any evidence of heating of the large scale corona in association with such events?
- To study the morphology of the magnetic structures within an EE (such events have sizes comparable to the current and past spatial resolution).
- The spectra will allow a detailed study of the small–scale brightening that will occur under the EUS slit and provide, hopefully, a way to associate the EEs (defined from the spectral signature) with the structures that are observed to brighten by HRI.
- If particles are accelerated during the reconnection process we may be able to detect them at the spacecraft during the near co-rotation phase.
- Observations of equatorial holes during the early phase of the mission and of the polar coronal holes (during the extended phase) will provide information about the relevance of the above transients on the acceleration of the solar wind.

EUS instrument requirements

1. Emission line requirements

Bands 6, 7a and 7b from the wavelength selection document. Spectra of selected strong lines formed at temperatures from 10^4 K to 10^6 K. A good selection could be H I Ly α (2×10^4 K), Si III 120.6 nm (8×10^4 K), N V 123.8 nm (1.8×10^5 K), Ne VIII 77.0 nm (6.3×10^5 K) and the Mg X 62.5 nm (second order) line (1×10^6 K).

2. Spectral resolution requirements

Profile needs to be resolved in order to study line shifts and widths. A spectral resolving element of 0.005 nm/pixel is sufficient (2 km/s in 1/7th of pixel at 100.0 nm). Spectral windows must be at least 0.2 nm large (40 pixel with 0.005 nm/pixel).

3. Spatial coverage

The typical scale on which to observe includes a couple of supergranular cells (L around 3×10^4 km). This study should consist of a 500"×500" raster (at 0.22 UA) followed by a sit-and-stare time serie.

4. Time resolution (incl. count rates)

The timescales to resolve are of the order of 10 s. Required count rates: at least 70 counts in 10 s. On quiet Sun such count-rates are achieved by all the listed lines. The produced data rate (12 bps) would be 5x500x40x0.1x12=120 kbps, roughly 7 times the available rate. Some amount of data compression may be needed.

5. Requirements for other instruments

Imaging capability at coronal and transition region temperatures is important for placing the spectroscopic measurements in context and study the morphology and evolution of the selected region. EUI-HRI images in Lyman alpha and Fe IX 17.1 nm. VIM Magnetograms to allow structures to be related to magnetic features are also required.

6. Other requirements

N/A

Relation to Solar Orbiter science goals

1. Determine the properties, dynamics and interactions of plasma, fields and particles in the near-Sun heliosphere

N/A

2. Investigate the links between the solar surface, corona and inner heliosphere

The study will address the relationship (if any) between the different dynamic transients characterising the solar quiet atmosphere and their relation with the strength and topology of the magnetic field. The quasi co-rotation phase will provide a chance of relating the small scale activity with *in-situ* measurements.

3. Explore, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun's magnetized atmosphere

The high latitude orbits during the extended phase would allow a detailed study of the small-scale dynamics within the polar coronal holes and to compare it with that observed in the quiet areas.

4. Probe the solar dynamo by observing the Sun's high-latitude field, flows and seismic waves

N/A