Quiet Atmospheric Heating and Initial Solar Wind Acceleration by Magnetoconvection

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The commonly held belief that the relentless action of magnetoconvection-driven magnetic reconnection is a ready source of energy and mass to the outer solar atmosphere has recently been investigated and verified [McIntosh et al. 2006, "Observations Supporting the Role of Magnetoconvection in Energy Supply to the Quiescent Solar Atmosphere", Submitted ApJ July 2006; McIntosh, Davey & Hassler, 2006, ApJL, 644, 87]. The results discussed in these papers are based on a self-consistent interpretation of equatorial coronal hole and quiet Sun spectroheliograms the 1530-1555Å range. Since SoLO will observe polar holes as though they were equatorial holes from SOHO's point-of-view this kind of study will be commonplace. We demonstrate the connection between the resulting energy release and partitioning of the plasma with the small-scale and global magnetic environments through the spectroscopic patterns of reconnection ejecta (e.g., spicules) observed in the upper chromosphere (Si II), through the transition region (C IV), and into the lowest portions of the solar corona (Ne VIII, Fe XII). This work closes the connection between the supergranular chromospheric network and energy release into the quiet corona and low solar wind in coronal holes. Critical to this analysis was the identification of Doppler signatures in the middle of the transition region (C IV) that are consistent only with the patterns produced by the constantly emerging, moving and reconnecting magnetic flux that are driven by magnetoconvection.

This investigation was made possible by a new, self-consistent, wavelength calibration using lines of Si I (assumed to have no net-Doppler shift) in the wavelength range of choice [Davey, McIntosh & Hassler, 2006, ApJS, 165, 368]. This post-reduction step can be performed on any observation in the 1550Å (or 1240Å [EUS Band 7b] - using lines of C I; Davey & McIntosh 2006 in prep.) wavelength channel allowing EUS to accurately calibrate every spectrum acquired and monitor channel degradation over the course of the mission. In short, careful choice of the wavelength range (according to the calibration) will permit unparalleled science to be performed simply because the spectra contain accurately computed Doppler velocities.

While it is possible to repeat this process/analysis exactly with EUS (band 9) we see a couple of shortcomings: only having a couple of lines in the central portion of the transition region and the engineering difficulties (see Peter Young's document) make it advantageous to look at slightly shorter wavelengths. As we have said above, the same calibration technique can be performed on Band 7b as long as the intensity suppression does not extinguish the C I lines in the spectrum, this is currently under investigation. With band 7b we will be able to study the energetic partitioning of the plasma in open and closed magnetic regions with a finer temperature sampling (Ly-A, He I, C I, Si II, Si III, C III, N V, OV, Mg X) and Doppler accuracy that may allow a re-evaluation of the detailed energy balance in the dynamic transition region, e.g., Peter & Judge (1999; ApJ, 522, 1148).

In addition to the direct magnetoconvection-driven heating and acceleration of the plasma, there are other effects to be considered that occur naturally as a result of the relentless magnetic topology changes induced on and around the supergranular boundary that have impact on the energy balance of the chromosphere. For example, the release and propagation ("leakage") of energy-laden *p-modes* from the solar interior [Jefferies et al. 2006, "Magneto-acoustic Portals and the Basal Heating of the Solar Chromosphere" submitted ApJL; also De Pontieu et al. 2004, Nature, 430, 536] that can possibly propagate into the solar corona and eventually into the solar wind IF the plasma conditions are correct [McIntosh & Jefferies 2006, "Observing the Modification of the Acoustic Cut-Off Frequency By Field Angle Inclination" in press ApJL]. Wave studies of this type are possible with the SoLO EUS Band 7b channel configuration in "sit and stare" or a very rapid raster mode over a small spatial range (~20-30Mm). We will be able to look at the spectra and evaluate the phase relationships of the line intensities and Doppler velocities to look for propagating waves and to estimate their energy content as it changes from the chromosphere, through the transition region and into the corona. The potential for "discovery science" is immediate: finding and identifying the magneto-atmospheric waves that are propagating into the low solar wind and into the heliosphere.

The results discussed above (McIntosh et al. & Jefferies et al.) combine to suggest that wave and reconnection-driven plasma heating occur in close proximity to one another. If they do not occur in precisely the same location they are separated by a pressure scale-height or so (depending on the plasma topology) inside an elementary flux "tube" (spicule) as a direct consequence of the ubiquitously driven stirring and readjustment of small-scale magnetic fields on the Sun. The ubiquity of the process is exactly the condition needed for a viable quiescent, or "basal", energy release mechanism.

SoLO (and EUS) will allow us to study small-scale transient and dynamic phenomena that all appear to be spatially, spectrally and temporally connected to magnetoconvection (at the scale of supergranulation). Observing these phenomena over the course of the mission will allow us to probe the detailed energy balance of the solar atmosphere and wind as a function of the evolving magnetic field. As an ancillary point, we will also be able to "clean up" the confusion present in solar glossary - looking to the underlying physical mechanism responsible for the signature observed rather than simply giving it a new label based on the wavelength it is observed in.

EUS instrument requirements

1. Emission line requirements

Band 7b will allow accurate calibration of the spectra and study of the features discussed above. Ly-a will allow coalignment with ground-based observatories as well as providing an interesting look at the biggest (radiative) energy sink in the solar atmosphere and coupling to ground-based oscillation experiments that we hope to have running by that time.

2. Spectral resolution requirements

Full spectral range is needed with resolved profiles in each exposure with sufficient spectral resolution to get close to 1km/s final calibration.

3. Spatial coverage

Most of the features discussed above can be studied over a supergranular spatial range of (~20-30Mm) although the ability to perform context rasters for combination with EUV imagers, etc is VERY important.

4. Time resolution (incl. count rates)

Flexibility depending on the science studied. To get accurate calibration in the neutral lines we may need to come up with a scheme of deep exposures (~200s) before each sequence or once a day, but this may need the Ly-a line to be mechanically masked to prevent damage. We estimate that 100 counts across each of the neutral "candle" profiles will provide a very accurate calibration for the spectra. If a daily calibration scheme is operated the spectra can be acquired quickly to resolve the rapid (spatial and spectral) evolution of the emission line profiles.

5. Requirements for other instruments

Several EUV/UV context imaging channels [these might include a Ly-a channel for cross-calibration with the long-wavelength channel, possibly a full-disk Doppler imager in the same line - a MOSES-like design will give both]. Definitely need a magnetograph for reliable $B_{||}$ measurements off of the Earth-Sun line as well as full disk photospheric Doppler imager. These can possibly be rolled into one instrument (e.g., SOHO/MDI).

6. Other requirements

Any other information that is important for the study.

Relation to Solar Orbiter science goals

Indicate how your science fits in with the four Orbiter science goals. Simply type "N/A" if it's not applicable to a science goal.

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

The science outlined above will provide direct (quantified) physical information about the relentless dynamic material and energy input at the base of the Sun-Earth connection.

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

These observations will provide SoLO with a unique viewpoint to couple relentless action of magnetoconvection that explicitly couples the solar interior to the inner portion of the heliosphere.

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

At all latitudes and especially out of the ecliptic plane, we will be able to look at the smallest, most dynamic, building blocks of energy release in the solar atmosphere and their impact on its energy balance of the magnetic Sun.

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

Chromospheric oscillation data from a full disk photopsheric and Ly-a Doppler imagers will allow us to look (in collaboration with other studies) at the portion of *p-mode* leakage [Jefferies et al. 2006] into the chromosphere and upper atmosphere that can be compared to helioseismic measurements from Earth and other orbital observing platforms (SDO/HMI).