

## First results from SOHO on waves near the solar transition region

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**Abstract.** We present first results from simultaneous observations with the CDS, EIT and SUMER instruments<sup>1</sup> onboard SOHO and the VTT at Tenerife. Our aim is to study the wave propagation, shock formation, and transmission properties of the upper chromosphere and transition region. The preliminary results presented here include the variation of velocity power spectra with height, difference in power between inter-network and network regions, and variations in mean flows displayed by different spectral lines.

### 1. Introduction and Observations

Our understanding of the energy transport in the solar atmosphere is still rudimentary. The unsolved problem of the non-radiative heating of the chromosphere and corona requires a closer look at the wave dynamics of the transition region. For example, recent work of Harvey et al. (1993, 1996), Jefferies et al. (1996), and Steffens et al. (1995) indicates the existence of a resonant oscillation while Deubner et al. (1996) present phase jumps as evidence for standing-wave nodal layers. Such features may be due to wave reflection above the chromosphere (e.g. Steffens et al. 1997), in particular at the steep temperature gradient of the transition region. On the other hand, chromospheric waves may be highly nonlinear and effectively raise only the mean intensity rather than the mean temperature (Carlsson & Stein, 1994). Facing this enigmatic situation, we need to study wave dynamics over the whole height range between the chromosphere and the corona with differentiation between different regimes such as quiet-sun network and internetwork regions. We obtained pertinent data with CDS, EIT, and SUMER onboard SOHO and the VTT at the Observatorio del Teide during two campaigns in June and September 1996, comprising 15 days in total.

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<sup>1</sup>please refer to *Solar Physics* 162 (1995) for a description of the instruments

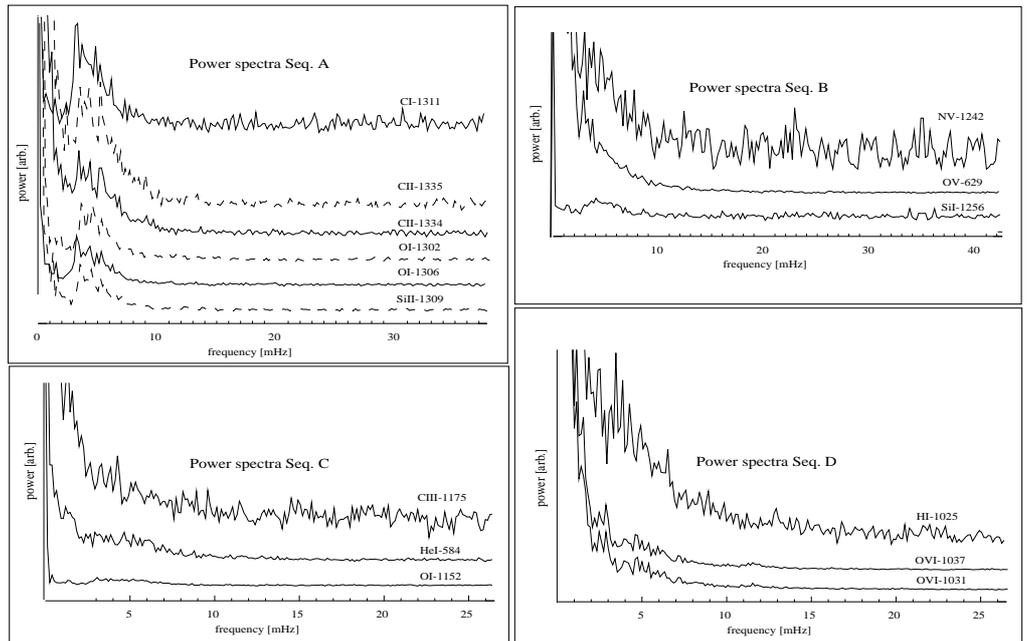


Figure 1. Velocity power spectra of the indicated lines, observed with SUMER in four observing sequences (A–D). The power scales are the same for each sequence, but with arbitrary offsets.

These are disk-center quiet-sun data sequences with durations from 30 minutes to 4 hours, many with simultaneous recording by multiple instruments. The sequences consist of filtergrams taken in 30 and 7.5 s cadence (EIT and VTT, respectively) and spectra from CDS (15 s) and SUMER (14.5 or 7.25 s depending on the choice of lines - see Fig. 1). The VTT was set to scan its slit across  $15''$  around the pointing position of the SOHO instruments. In total, 26 spectral lines were observed that cover the atmosphere from photosphere to low corona.

## 2. First results

Figure 1 shows velocity power spectra derived from SUMER spectrograms, Fig. 2 the corresponding RMS velocities and Fig. 3  $x-t$  “time-slice” diagrams. The lines may be divided into two types. The first (marked with circles in Fig. 2) are formed at fairly low height and display prominent  $x-t$  oscillatory patterns with about  $5''$  spatial coherence especially in velocity (see the CI line in Fig. 3) that produce a distinct velocity power peak around  $f = 3$  mHz (Fig. 1). They have comparatively low RMS velocities (Fig. 2) — although distinctly larger than the ones reported from lower-resolution OSO 8 data by Athay & White (1980). The lines of the second category (crosses in Fig. 2) are formed higher up. They show noisy  $x-t$  diagrams that are less oscillatory but have occasional high-velocity events that are often irregularly repetitive (see e.g. OV in Fig. 3). Their power spectra have no distinct peak, but nevertheless contain high power up to 10 mHz combined with comparatively large RMS velocities.

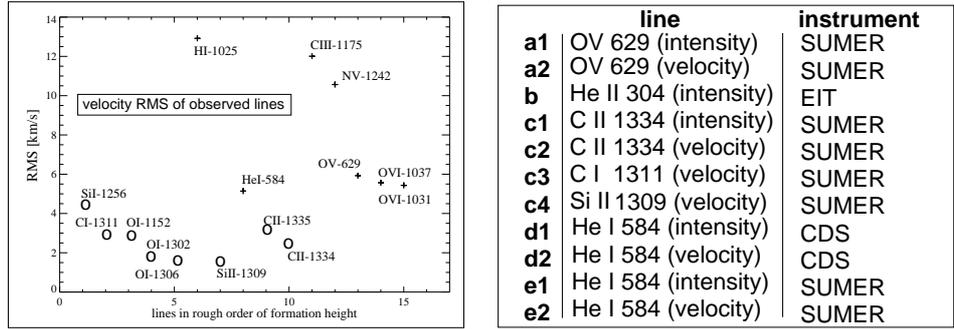


Figure 2. Right: RMS velocities of the Lines observed with SUMER. Left : Line information for the panel below

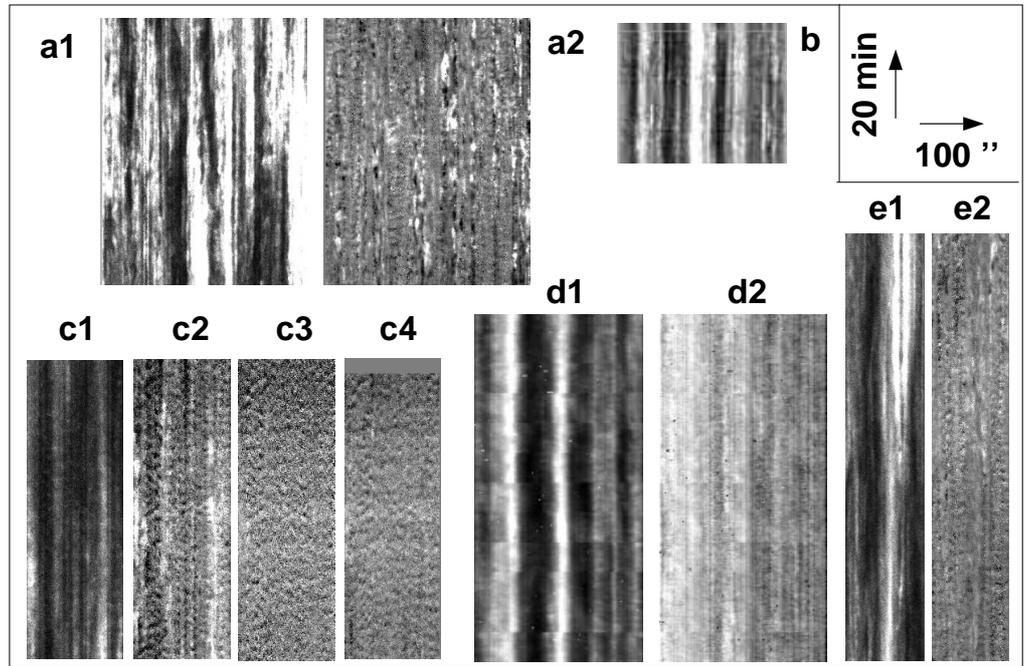


Figure 3. selected  $x - t$  diagrams, velocity coded bright for redshift. All diagrams are equally scaled. The right panel of Fig. 2 displays the associated line information

These two dynamical behaviors are intrinsically different; each requires detailed investigation. The HeI584 line is about at the transition between the two. In Fig. 4 we turn to distinctions between the network (cell boundary, cb) and internetwork (cell interior, ci) regimes. The distinction was made by averaging intensities over extended duration. Both HeII304 intensity observed with EIT and HeI584 intensity observed with CDS show a peak in the cb/ci power ratio near  $f = 3$  mHz. There is no such peak in the cb/ci Dopplershift power ratio, neither in the CDS data (Fig. 4) nor in the SUMER data (not shown). We believe that this striking difference is not due to horizontal motions that might

parade as intensity changes, since the intensity power shows no enhancement at the flanks of the network areas. We therefore speculate it may reflect magnetic

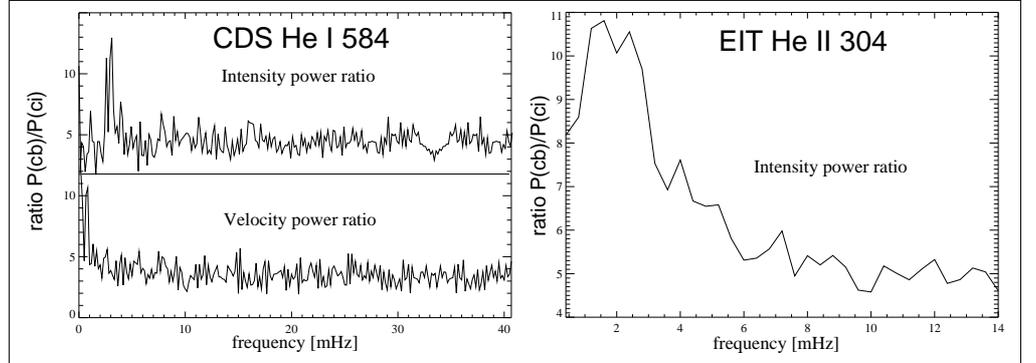


Figure 4. Ratio between network (cell boundary, cb) power and internetwork (cell interior, ci) power, for the velocity (CDS) and the intensity (CDS and EIT) of He I 584 and He II 304.

sausage modes, compressing and heating network elements without vertical displacement. Finally, Fig. 5 compares the average velocity behavior between four different lines. The abscissae measure, per  $(x, t)$  measurement of each line, the mean intensity in C II for sequence A, and He I for seq. C (Compare Fig. 1 for the specification of the sequences) averaged over 30 min around time  $t$  at location  $x$ . Low values denote internetwork, high values network. The ordinates are the corresponding velocity values per  $(x, t)$  averaged over narrow abscissa bins.

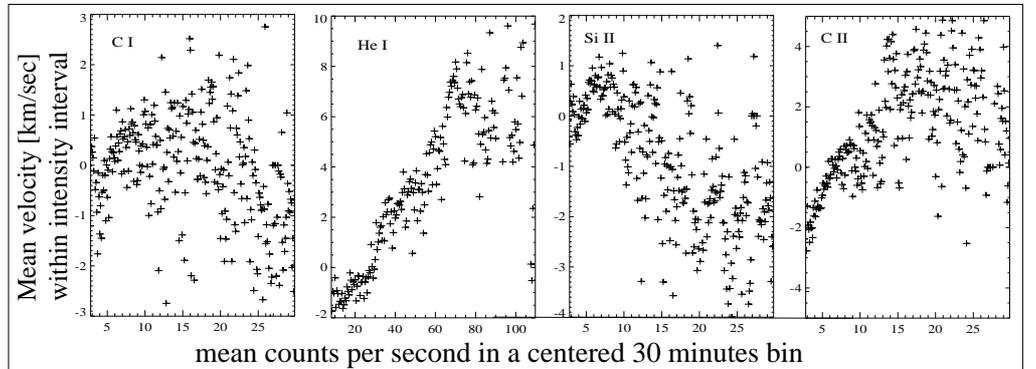


Figure 5. Velocity averages for four SUMER lines as function of the temporally averaged intensity of Si II (Seq. A), and He I (Seq. C). Positive velocities denote redshift (downdraft).

Thus, characteristic average ci velocities are displayed in the lefthand part of each diagram, characteristic average cb velocities in the righthand parts. The scatter increases to the right in each diagram because less surface area contributes at larger mean intensity. The CI 1311 line mostly shows small average downdrafts, except for the darkest and brightest areas. The He I 584 line pro-

duces a distinct slope between small upward flows in ci and very large mean downflows in cb. The SiII1309 line shows a slope change between the two domains, while the CII 1334 line again has a pronounced positive slope with increasing mean intensity. These intriguing results indicate that different lines behave very differently. They differ in height of formation, in response to velocity perturbations, in optical thickness and also in their first ionization potential (FIP). Elsewhere in these proceedings, Rutten (1997) calls attention to the so-called FIP effect and proposes that the required element segregation may occur through ci/cb dynamics if low-FIP ions preferentially collect in ci canopies and then flow down into cb network. Figure 5 may indicate such ci FIP difference since the low-FIP Si ions do not share the average ci updrafts of the high-FIP elements He and C. However, the cb difference between the SiII and the HeI plus CII panels is more striking and does not support Rutten's suggestion. It implies that low-FIP elements may preferentially migrate up in the network while high-FIP elements migrate down, or it may be due to intrinsic difference in line formation. These puzzling results certainly deserve a more detailed analysis.

### 3. Outlook

The plots above represent a statistical approach to studying wave propagation and shock formation around the transition region. In addition, we aim to study single events and investigate instantaneous local Doppler shifts and waveforms. We plan to select internetwork Ca IIK grains as the most dynamical events in the quiet chromosphere, and to trace their signature higher up.

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