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Internetwork Grains with TRACE

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Abstract. We demonstrate that TRACE data are well suited to studying internetwork grain patterns. We first show that wide-band Ca II K filtergrams register spatio-temporal internetwork morphology including the occurrence of K_{2V} grains, although the latter are a narrow-band phenomenon. We then show that the TRACE near-UV passbands image the same morphology. TRACE does so free of seeing deformations, over long times and large areas, and adds photospheric context as well.

1. Introduction

Ca II H_{2V} and K_{2V} grains thank their name to their appearance as spectrally narrow peaks just to the blue of line center in Ca II H & K spectrograms, without corresponding emission on the red side. This property distinguishes them from the network emission, which is also grainy in spatial morphology but spreads symmetrically over the full H & K cores and inner wings. Other differences are that K_{2V} grains appear exclusively in the internetwork regions, appear intermittently at intervals of a few minutes, and appear only a few times at a given location. Yet another difference is that the spectral formation mechanism of the K_{2V} grains is largely understood as a signature of weak acoustic shocks (Carlsson & Stein 1997; cf. reviews by Rutten & Uitenbroek 1991, Rutten 1994, 1995, Rutten et al. 1999), whereas the network emission mechanism, although undoubtedly betraying magnetic heating of some kind, is not identified.

2. Passband comparison

Studying the spatio-temporal patterns in which H_{2V} and K_{2V} grains appear is hard to achieve with a spectral passband as narrow as the peaks themselves, because that requires the spectral resolution of a spectrograph rather than a filtergraph and therefore brings a lack of spatio-temporal coverage. Fortunately,

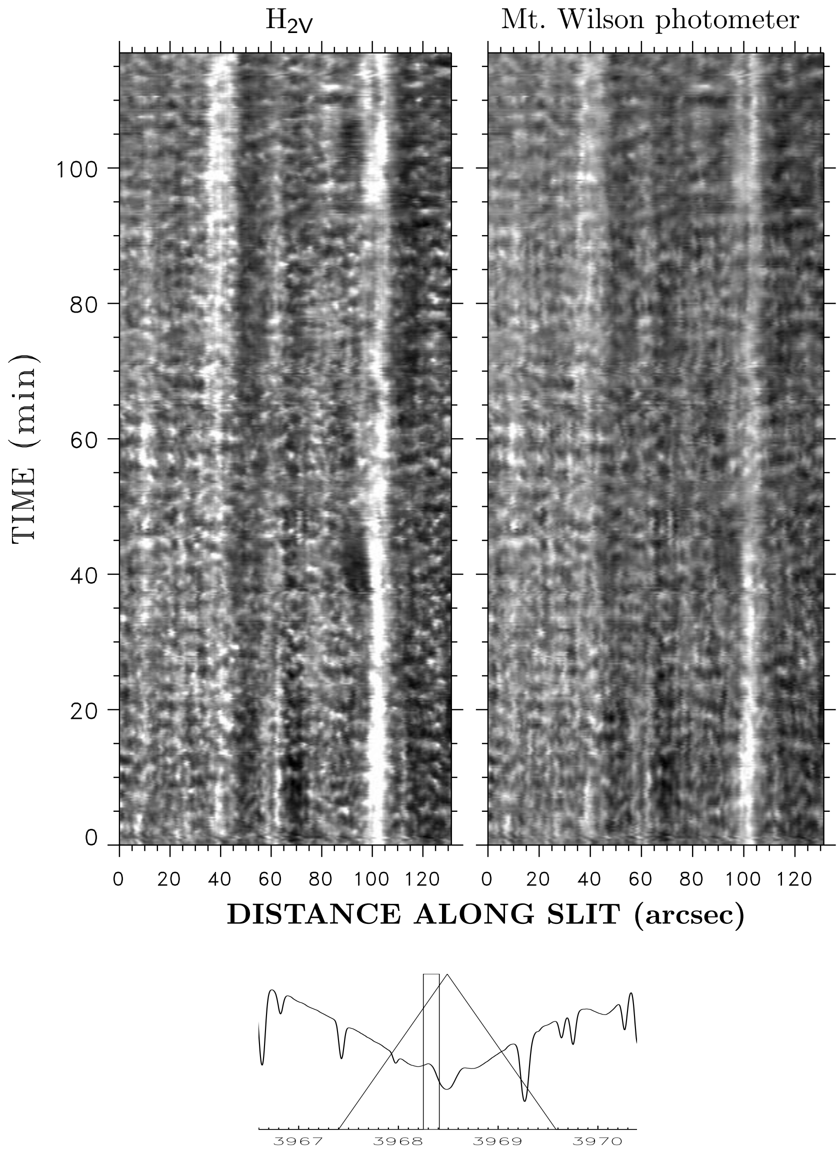

Figure 1. Comparison of internetwork grain signatures between different passbands from Ca II H spectrograms obtained with the horizontal spectrometer of the NSO/Sacramento Peak Dunn Telescope. The upper panels are "time slices" that display the spatio-temporal evolution of the intensity integrated over the passband defined in the lower graph. Left: integration over a narrow rectangular H_{2V} passband that selects only the H_{2V} peak blueward of the Ca II H line center. Right: integration over a triangular passband corresponding to the transmission profile of the Mt. Wilson stellar H & K photometer. Bottom: corresponding segment of the NSO solar flux atlas of Kurucz et al. (1984) downloaded from ftp://ftp.noao.edu/fts/fluxatl/ with the two passband profiles superimposed.

however, a much wider passband suffices. This is demonstrated by Fig. 1 which is constructed from a Ca II H spectrogram sequence taken with the Richard B. Dunn telescope at NSO/Sacramento Peak in 1991. The upper panels are $x - t$ diagrams that were obtained by spectral integration over the passbands shown in the lower graph. The lefthand panel is for a narrow band that isolates H_{2V} grains conform their spectral appearance. The righthand panel holds for the much wider triangular passband defined by the slits of the stellar H & K photometer at Mt. Wilson (Vaughan et al. 1978). Comparison of the two panels shows that the spatio-temporal patterns are virtually the same, even though the one at left is considerably sharper. The bright vertical stripes mark chromospheric network; in between is internetwork. Especially the rightmost internetwork area, with $x = 105 - 130$ arcsec, displays a stream of well-defined characteristically flashing H_{2V} grains. They appear less focused and less bright in the wide-band panel, but they are present there as well with very much the same spatio-temporal occurrence pattern. Only when these two panels are computer-blinked against each other does one notice a small phase shift, in the form of grains jumping slightly up and down with the narrow-band ones appearing slightly later than the wide-band ones.

The reason for the large similarity is that the H_{2V} grains appear as part of a more or less standard spectral evolution sequence in which bright "wing whiskers" (Beckers & Artzner 1974) develop and contract towards line center (Figs. 4–5 of Cram & Damé 1983, Fig. 2 of Rutten & Uitenbroek 1991, Fig. 3 of Hofmann et al. 1996, Figs. 16–17 of Carlsson & Stein 1997). They correspond to the upward propagating acoustic disturbances that become shocks slightly later and slightly higher up, and then produce peaks at the H_{2V} wavelength. The wider passband samples a larger contribution from these whiskers, but its high correspondence with the narrow-band panel shows that their spatio-temporal occurrence pattern is essentially identical to that of the grains proper.

The good agreement implies that, thanks to the presence of the whiskers, Ca II K filtergrams with passbands of a few Ångstroms sample K_{2V} grain patterning quite well — apart from the small phase difference and the loss of contrast. The contribution by Smaldone *et al.* in these proceedings demonstrates that the apparent grain density becomes smaller for wider passband at a specified contrast, but simple rescaling of wider-band filtergrams to the display dynamic range serves to map K_{2V} grain occurrence adequately. Examples of internetwork grains on high-resolution 3 Å Ca II K filtergrams are shown by Lites et al. (1999).

3. Filtergram comparison

Figure 2 shows a small segment of a quiet-Sun field observed by TRACE in its three near-UV passbands. The fourth panel (bottom) is a co-spatial and co-temporal Ca II K filtergram taken with the 3 Å filter at the Swedish Vacuum Solar Telescope (SVST) on La Palma. The TRACE images were rebinned to the SVST pixel resolution. They have lower angular resolution, but there is nevertheless a high degree of spatial agreement between the Ca II K SVST image and the TRACE images, in particular the 1700 Å one. Thus, at their resolution

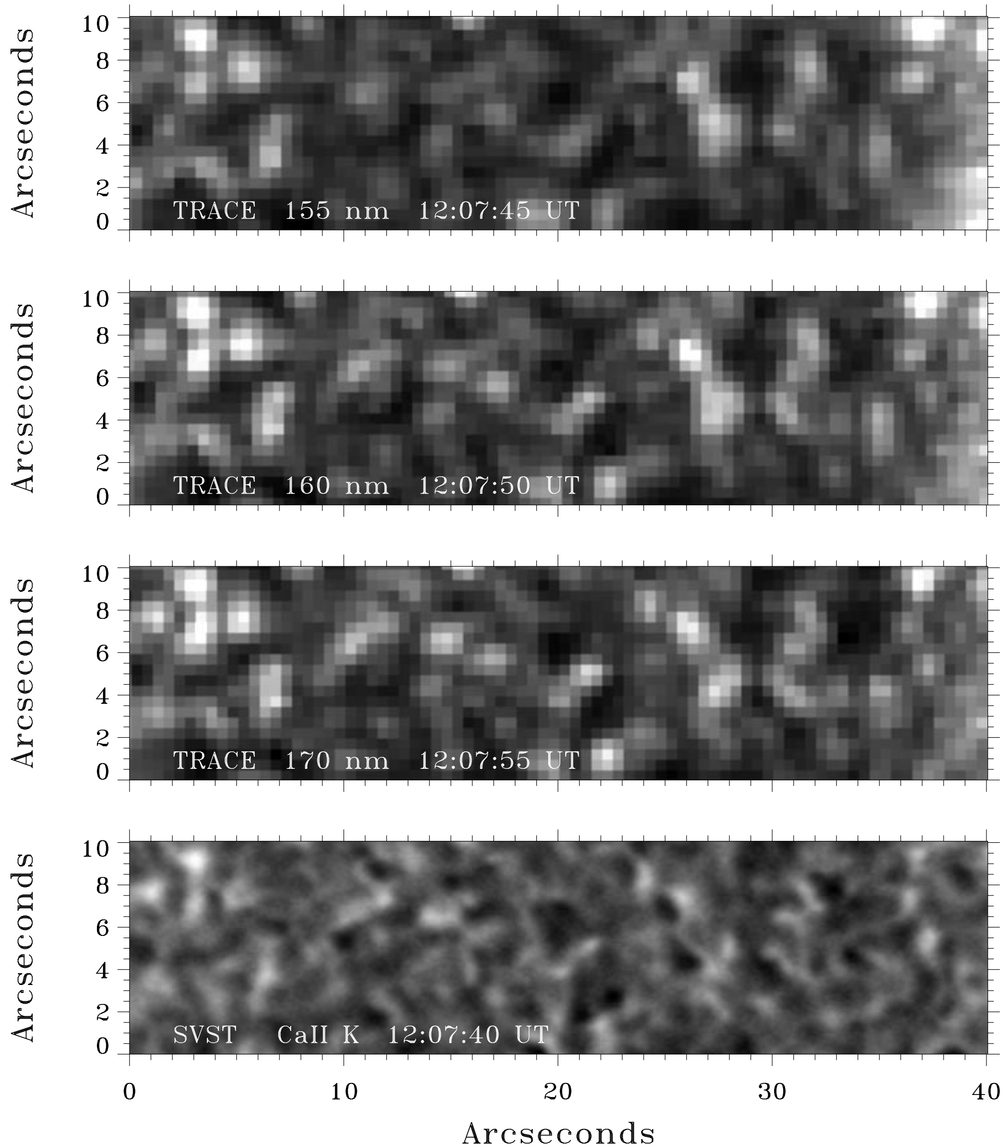

Figure 2. Enlargements of a small subfield covering a quiet solar region of filtergrams taken on May 30, 1998 at the specified times. Bottom panel: high-resolution Ca II K image taken with the SVST. Other panels: nearly simultaneous TRACE images taken in the three near-UV passbands as specified. The SVST and TRACE images were co-aligned using a larger field containing an active region.

these TRACE channels portray internetwork grain phenomena about as well as Ca II K filtergrams do[1].

4. TRACE as grain tracer

TRACE observing collects images without interruptions from night or clouds or bad seeing. There are no rubber-sheet pattern deformations as in ground-based observing. In addition, TRACE collects much larger spatial samples than can be achieved with spectrometry. Therefore, TRACE image sequences provide an excellent means to study spatio-temporal grain occurrence on time scales from tens of seconds to many hours. In addition, combined analysis of co-spatial and co-temporal white-light images from TRACE should serve to relate grain patterns to photospheric convective patterns down to granular scales, again without degradation from seeing, and permit improved studies along the lines of Hoekzema et al. (1998) and Hoekzema & Rutten (1998) for large data sets delivering high statistical significance.

In terms of Fourier characteristics, we expect to find intensity modulation power spectra similar to those derived from the Ca II infrared lines by Deubner & Fleck (1990) and from the 1 Å wide Ca II H-index by Lites et al. (1993a), *i.e.,* sampling the same layers that produce the whiskers in the inner wings of Ca II H & K. Power spectra from this upper-photospheric domain are characterized by high power at low frequency in both network and internetwork, a power dip around $f = 2$ mHz, and a power peak around $f = 4$ mHz that is higher and extends to higher frequencies for internetwork than for network. The low-frequency component may partially be due to gravity waves (cf. Lites *et al.* 1993a, 1993b).

The morphology in the 1600 Å and 1550 Å panels of Fig. 2 differs increasingly from the morphology in the 1700 Å and Ca II K panels. This may be due to the presence of signal with different nature from appreciably higher levels. The 1550 Å passband contains lines of C I and of C IV; in active regions, the latter contribution dominates whereas in the internetwork the C I lines may constitute most of the signal. However, the differences may also betray temporal retardation with respect to the lower layers sampled by 1700 Å and Ca II K. We have embarked on Fourier phase difference analysis to see to what extent this is the case.

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[1] We therefore feel that K_{2V} grains should be called "internetwork grains" more generally.

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