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Quasi-regular structures in the solar photosphere (trenching in the brightness relief): Algorithmic treatment

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Abstract. The results of applying two algorithmic techniques to time-averaged images of the solar granulation are presented. Some quasi-regular structures, which are hidden in the intense noise due to the presence of light blotches in the images, can be detected in this way.

Keywords. Sun: photosphere, Sun: granulation, convection

Introduction. As reported previously by Getling & Brandt (2002), the procedure of time averaging (over 1–2 h) applied to the La Palma series of solar-granulation images (Simon *et al.* 1994) reveals long-lived, quasi-regular photospheric structures on a meso- or supergranular scale in the form of concentric rings or parallel strips (circular and linear "ridges" and "trenches" in the brightness relief). These systems resemble some roll patterns known from laboratory experiments on Rayleigh–Bénard convection and may be an imprint of the pattern of subphotospheric convection.

It is now apparent that such structures are not unusual in the photosphere (Getling 2004, 2006). In addition, as will be demonstrated below, specific "web patterns" can be observed in some cases. However, the structures are obscured by intense noise associated with the presence of numerous light blotches in the averaged images, so that the signal-to-noise ratio is very low. For this reason, we employ some techniques of data processing to make the structures better recognizable.

Algorithmic treatment of averaged images. By the moment, none of the tested algorithms has been found to be universally capable of filtering out the noise and detecting the ordered component of the averaged-intensity field. Nonetheless, some noteworthy features can be revealed using the algorithmic processing of the averaged images.

Analyses of azimuthally averaged brightness distributions. We have developed an algorithm that scans given rectangular areas in the image, uses each point as a trial centre, computes the radial distributions of the azimuthally averaged intensity, and plots rings at the local maxima of the averaged intensity. A detailed description of this algorithm can be found in Getling (2006).

An example of applying it to time-averaged granulation images is given in figure 1. Here, the centre detected in area 0 corresponds to a system that includes a pronounced ring about 8 Mm across, a much fainter ring (hardly discernible by eye) about 21 Mm

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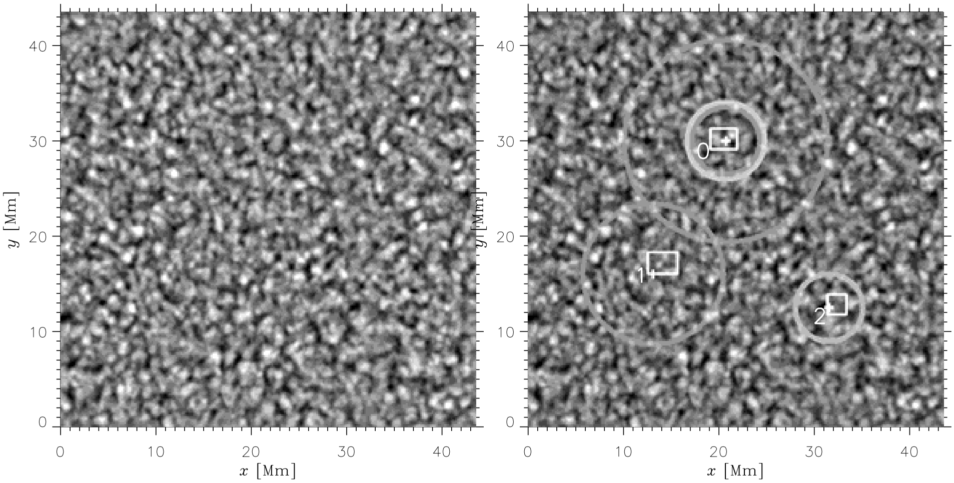

Figure 1. *Left:* sample 2-h-averaged image of the La Palma series; *right:* same image superposed with patterns of azimuthally averaged intensity for the most likely positions of the centres of ring systems (crosses) detected by our algorithm. The scanned areas are marked with white rectangular frames and numbered. A common intensity scale is used for all centres. A web pattern can be distinguished in the original image — its centre is located within the area labelled as 0 in the lower panel.

across, and radial "spokes" within the smaller ring. On the contrary, the ring centred in area 1, which is very faint and isolated, simply represents the maximum of the radially averaged noise intensity and seems to have no physical meaning. Apparently, this also applies to area 2, where the plotted ring is likewise isolated and faint.

Thus, although this algorithm is fairly sensitive to the level of noise in the analysed intensity field, it can nevertheless be used, with due care, to test hypotheses of the presence of faint ring systems.

Application of an algorithm intended for aerospace-image processing. We also used the algorithm and software package developed by Salov (1997) at the Institute of Computational Mathematics and Mathematical Geophysics (Novosibirsk, Russia) to detect linear and circular geological structures in aerospace images of the Earth's surface [see also Buchnev *et al.* (1999)].

Figure 2 exemplifies the results of such a procedure. The program was run in the mode of seeking linear structures (lineaments). Curved features could generally be described as chains of lineaments of varying length. Both light and dark lineaments were detected, and their graphic representation is most descriptive if they are plotted on a grey background (figure 2, right).

The most remarkable feature in this map of lineaments is a pronounced trenching pattern that includes families of parallel, alternating light and dark lineaments and chains of lineaments. In some cases, lineaments forming different patches of this pattern can be connected, and fairly extended families of lineaments can thus be obtained. It is to such objects that a physical meaning should be attributed in the first instance.

In the case presented in figure 3, the application of the same technique reveals a web pattern in the lower left quadrant of the image.

Conclusion. The above examples demonstrates that, although much care must be taken in applying image-processing procedures to granulation images, the results obtained by the moment show promise for the detection of hidden trenching patterns in time-averaged granulation images.

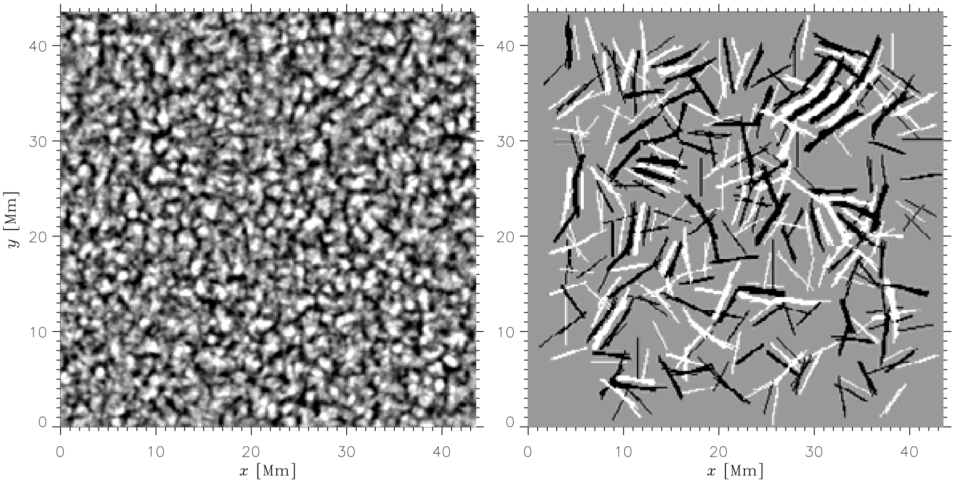

Figure 2. Processing of a sample 1-h-averaged image of the La Palma series with the use of Salov's algorithm. *Left:* original image; *right*: detected light and dark linear structures (lineaments) on a grey background.

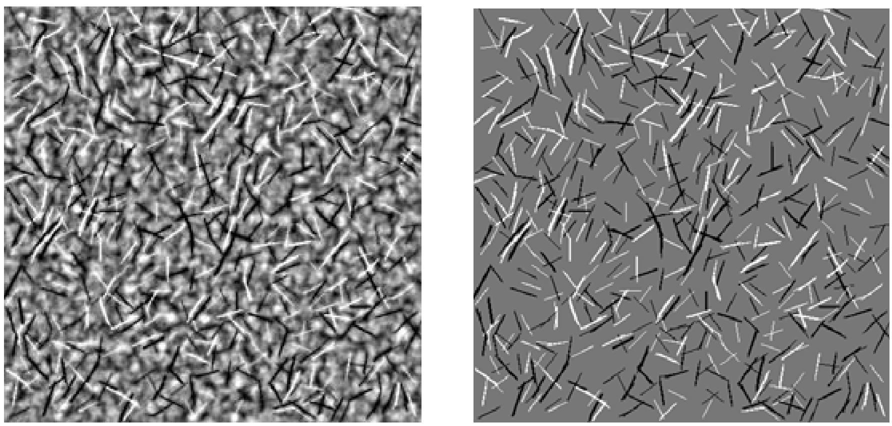

Figure 3. Processing of a 2-h-averaged image of the La Palma series with the use of Salov's algorithm. *Left:* original image superposed with the algorithmically detected light and dark lineaments; *right*: the same pattern of lineaments on a grey background. A web pattern can be distinguished in the lower left quadrant of the image.

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