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DYNAMICS OF THE QUIET SOLAR ATMOSPHERE: K_{2V} CELL GRAINS VERSUS MAGNETIC ELEMENTS

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ABSTRACT We employ high-resolution Ca II K_{2V} imaging to solve the controversy regarding Sivaraman and Livingston's identification of K_{2V} cell grains with magnetic elements.

Keywords: chromospheres; magnetism; hydrodynamics; stellar atmospheres

INTRODUCTION

The lower solar chromosphere is split into magnetic and nonmagnetic components. Both regimes are heated. The classical theory of acoustical heating now enjoys a revival: propagating sound waves and shocks may heat the nonmagnetic quiet chromosphere and so explain the "basal flux" observed in other cool stars (Schrijver *et al.* 1989). A pivot phenomenon in this context is the presence in quiet areas of the solar surface of tiny, short-lived emission features in a narrow wavelength band just to the blue of the Ca II K core, the "K_{2V} cell grains". They seem to be a direct manifestation of acoustical wave heating in the low chromosphere, but their nature remains elusive (review by Rutten & Uitenbroek 1991b).

An issue of controversy is whether these grains are of magnetic origin. Direct correspondence between K_{2V} cell grains and intranetwork magnetic field concentrations was observed by Sivaraman & Livingston (1982, see also Sivaraman 1991), but others doubt this result (Deubner 1991, Rutten & Uitenbroek 1991a, 1991b). We solve this dispute here with new observations; it turns out that everybody has been right. There are *two* distinct classes of Ca II cell-interior grains: *(i)*—oscillatory K_{2V} flashes, with 3–min periodicity, brief spatial memory, 5–10 per cell; *(ii)*—persistent K–line grains, retaining long-term identity while traveling through the cell and flashing with 3–5 min periodicity, about 1 per cell.

LA PALMA OBSERVATIONS

We use the Swedish Solar Vacuum Telescope on La Palma to study K_{2V} cell grains, combining the prototype OSL camera and the Lockheed narrow-band Ca II K filter with the Swedish video image grabbing system to obtain simultaneous and co-spatial chromospheric K_{2V} and photospheric granulation image sequences. Figure 1a is an image from a four-hour K_{2V} movie. It shows network as extended bright structures with smaller, grainy enhancements, and quiet cell interiors as darker areas at upper left and lower right. The latter contain K_{2V} cell grains, a bright one being marked by the crosshair intersection. Only bright K_{2V} grains are visible here; they would stand out more strongly for a narrower passband than our $\Delta\lambda = 0.03$ nm as is clear from the spectra published by Cram & Damé (1983).

Figure 1b is a "timeslice" along the horizontal crosshair, showing the evolution along the corresponding linear surface segment during a 56 min segment of the K_{2V} movie. The K_{2V} grain marked in the frame above is again at the crosshair intersection; the grain to the left of it appears at the same moment. Note the marked distinction between network and quiet areas in K_{2V} time behavior. The piece of network across the middle of the crosshair shows emission throughout this sequence, resulting in a columnar brightness streak with superimposed intensity oscillations of 5–min and longer periodicities. The quiet cell interiors show wispy brightness patterns on a dark background which mark the 3–min oscillation, generally present throughout quiet areas but reaching large brightness only in the more localized K_{2V} grains.

THE PERSISTENT FLASHER

Figures 2a and b are another K_{2V} image and timeslice combination. There is a bright grain below the center of the quiet cell in the upper-left quadrant of the image. On such single frames, it appears as just another K_{2V} oscillation flash, but our movie and timeslices indicate that this is a wholly different type of feature. On the movie it is seen to be a bright moment of a persistent feature which maintains its identity throughout the movie while flashing on and off in brightness. At the start, it is located higher up in this cell; it then travels towards the network at the lower part of the frame, which it reaches after about three hours. The timeslice was constructed along the track of this persistent flasher, during the hour ending when it reaches the network. The flasher demonstrates its longevity by producing a streak of brightness in the timeslice that is much more alike to the network brightness columns then to the wispy K_{2V} oscillation patterns.

Is this persistent flasher magnetic? There is no direct magnetic field diagnostic in our data; therefore, we turn the question around and ask whether similar features are seen in magnetogram movies. That is indeed the case. For example, the magnetogram movies taken by the Lockheed group at La Palma with the *SOUP* tunable filtergraph (Tarbell *et al.* 1990, Title *et al.* 1991) contain much plage but also cells without strong fields. The latter contain a few isolated magnetic features, typically one per cell, which also travel from cell center to nearby plage within a few hours.

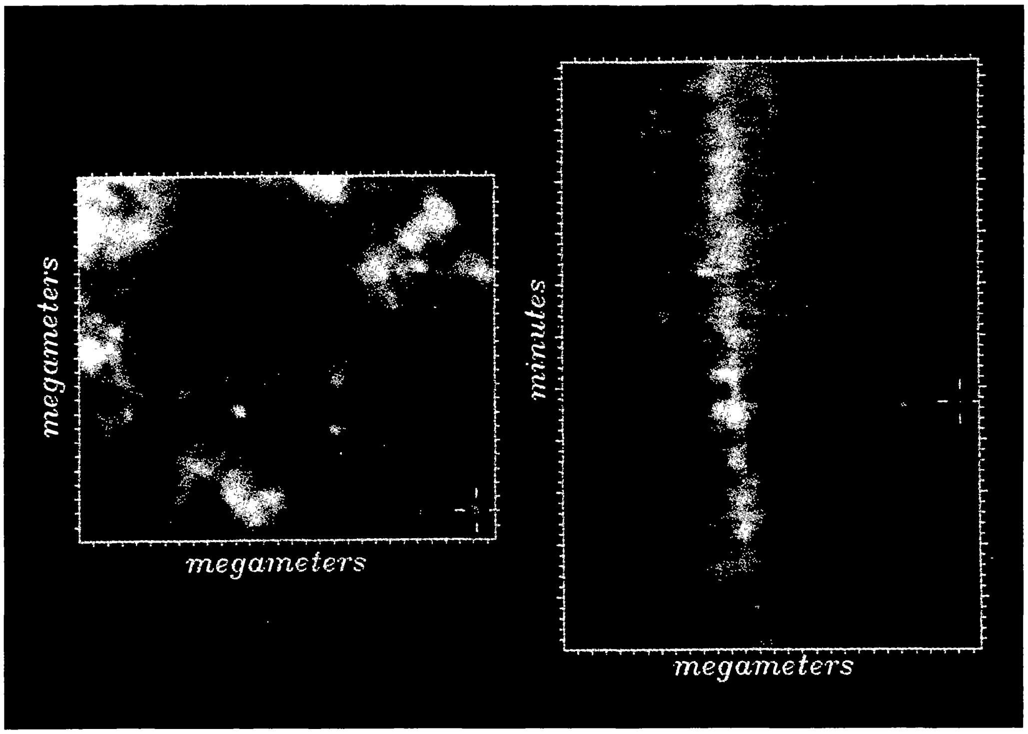

Figure 1. (a) K_{2V} image with a bright K_{2V} grain marked in the lower right hand corner. Each thick mark is 1000 km. (b) Space/time slice through the mark in (a) along the horizontal direction. The vertical axis is time with 1 minute tickmarks.

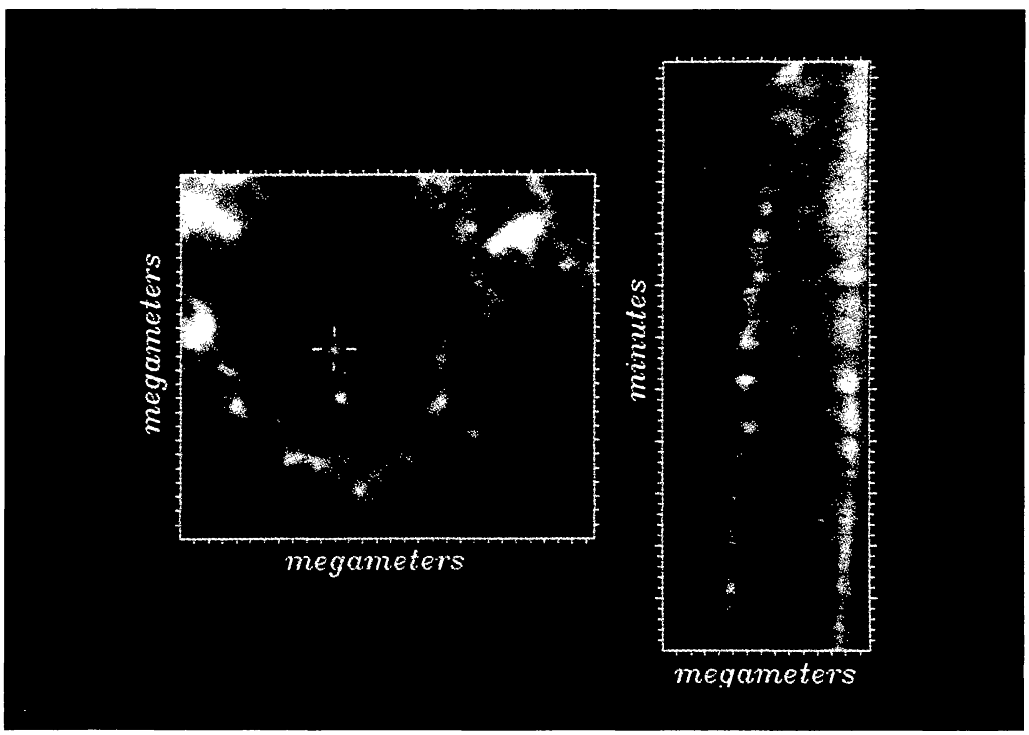

Figure 2. (a) K_{2V} image with a persistent flasher marked. (b) Space/time slice along the track of the flasher. Scales as in figure 1.

DISCUSSION

Sivaraman & Livingston used a 0.1 nm wide passband, equaling the integrated H–index of Cram & Damé (1983) in which only the very brightest K_{2V} features are seen. The best existing K_{2V} spectroheliograms have $\Delta\lambda = 0.01$ nm and show 10–20 K_{2V} grains per cell. Our $\Delta\lambda = 0.03$ nm passband is already too wide to observe the weaker grains properly; at $\Delta\lambda = 0.1$ nm, most are unobservable. Sivaraman & Livingston indeed observed only few grains per cell. The migration and long-livedness which these possessed indicate that they were of the persistent-flasher type, not regular K_{2V} oscillation grains. The observed spatial correspondence with intranetwork magnetic features then indicates that persistent flashers are indeed of magnetic nature.

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