LOCAL AND GLOBAL MAGNETIC OSCILLATIONS IN THE PHOTOSPHERE

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ABSTRACT

The solar influence on the terrestrial climate is typically associated to changes during the solar cycle, that is at timescales of years and more. In fact, the variability seems to be related to the magnetic activity. Nevertheless, the dynamic of the magnetic field is still not well understood. The characteristics of the processes acting at higher temporal frequencies (such as flares etc.) are clearly a signature of the long term magnetic changes and their investigation supports the understanding of the energy relaxing in the interplanetary space. Four hour full disk magnetograms (with a 4 arcsec/pix resolution) obtained in the Sodium D-lines have been analyzed pixel-by-pixel (locally) and in the $\ell - \nu$ diagram (globally). The magnetic oscillation have been detected at different frequencies and identified on the solar disk. Some oscillations have been correlated to the H$\alpha$ bright points as the signature of the magnetic reconnection and subsequent plasma out-flow.

1. INTRODUCTION

The solar magnetic field has been thought almost stationary for centuries. The 22 year cycle has usually been considered the only relevant change in the magnetism related to the dynamo process. A more complete understanding of the processes that lead to the solar cycle changes and the heating of the corona asks for further observations of the dynamic small scale magnetic structures of the Sun. Indeed, the measure of low and small magnetic fluxes and its interpretation in terms of magnetic field is not a trivial task. Most of the knowledge of the fast evolving magnetic structures is carried by indirect observations in the radio or in the Fraunhofer lines formed in the chromosphere, where the magnetic energy dominates. Data are often in disagreement when finding spatial and temporal correlation between Ca K bright points, magnetic field, Uv jets ecc. (Cook, Rutten and Hoekzema, 1996, Hoekzema, Rutten and Cook, 1997, Lites, Rutten and Berger, 1999) In the photosphere, the magnetic field fluctuations have been primarily framed in the research of the magneto-acoustic waves in spots (Lites, 1992, Lites et al. 1998, Horn et al., 1997, Cacciani et al., 1998, Ruedi et al., 1998), and recently in the quiet sun (Ulrich, 1996). Anyway, it seems reasonable that the magnetic field anchored to the base of the convective zone and dominated by the plasma motions up to the photosphere, is closely related to the chromospheric network behavior and the scenarios should match each other. Transition region explosive events have been correlated to magnetic cancellation as a consequence of the relaxed magnetic ropes upward expansion (Chae et al., 1998), but these cancellations are difficult to localize due to their small scales (1”). In the framework of the solar five-minute oscillations and their origin, the seismic flux has been found to be related to downflows in the intergranular lanes (Goode et al., 1998, Espagnet et al., 1996). This phenomenon has been invoked to explain the solar ”background” in the intensity (I) velocity (V) phase difference spectra (Skartlien and Rast, 2000) but no observational evidences of the relation between the magnetic flux and the downflows have been found yet. On the other hand, some observational evidences seem to attribute the inhibition of the p-modes power by the magnetic activity: velocity local seismology in magnetic regions has proofed the absorption of the p-modes power at low frequencies and its enhancement at the highers (Braun and Lindsey, 1999). A possible explanation of this apparent contradiction could be attributed to the presence of distinct processes involving the magnetic and the kinetic energy: the generation of the solar oscillations by continuous jets of plasma triggered by the magnetic reconnections and the interaction of the velocity field with the established, long term variable, magnetic field. In this paper we present the characteristic of the full disk magnetic oscillations in a day at the beginning of 1998. The results are similar for different days in that period of the solar cycle.

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pergranules have time-scales of 10 minutes and hours with dimensions of 1" and tenths of arcseconds respectively. The structures would lose their identity after a lifetime and a compromise has to be reached not to wash out anything but the rotation.

Figure 1. a dopplergram (left) and a magnetogram (right) obtained on 30 January 1998 at Kanzelhöhe. The upper frame in the magnetogram limits the selection shown in figure 2.

2. THE DATA ANALYSIS

The data consist of two sets of simultaneous dopplergrams and magnetograms obtained with a sodium Magneto-Optical Filter (MOF) at Kanzelhöhe on 30 January 1998. The images have been acquired every minute and 256 minutes have been selected for the analysis. The spatial resolution is 4.3 arcsec/pix. All the images have been calibrated (Moretti & the MOF Development Group, 2000) and registered. The full-disk data have been treated locally (pixel-by-pixel) and globally (using the spherical harmonics decomposition) to obtain the power distribution on the disk and the $\ell - \nu$ diagram. The daily trend has been removed in the pixel-by-pixel time-series using a polynomial fit, while a differential filter has been used in the spherical harmonics decomposition. The final spectra have been corrected for the filtering of the data.

Let us consider what a $\ell - \nu$ diagram is: the velocity (or whatever other signal) is filtered by some masks and the coefficients of its decomposition in these masks are displayed. In seismology, these coefficients are related to a global resonance but they still are the contributions to the signal, in a particular spatial scale and at a particular frequency. The modes are the components you need to explain a particular configuration in time of the distribution of the velocity on the solar surface. When the velocity and intensity oscillations are treated locally, their trait is different as the mixing with the local phenomena and their characteristic distributions on the disk is not washed out by a filter as the spherical harmonics do.

The local analysis uses a three-dimensional representation, as the distribution on the disk (in x,y) has to be visualized in function of the frequency ($\nu$). In fact, the images time-series are pixel-by-pixel fast fourier transformed (FFT) and the power and phase difference maps are obtained. This kind of analysis permits to investigate the distribution on the disk of the oscillating power and phase but cannot intrinsically achieve a high frequency resolution. In fact, long time-series would produce a spatial average because of the solar rotation and of the evolution of the structures on the solar surface. The granules and supergranules have time-scales of 10 minutes and hours with dimensions of 1" and tenths of arcseconds respectively. The structures would lose their identity after a lifetime and a compromise has to be reached not to wash out anything but the rotation.

Figure 2. The velocity power (top), the V-B phase difference (center) and the longitudinal magnetic power (bottom) for the selected upper area in figure 1 at 0.91, 2.47, 3.16, 3.78, 4.88, 5.53 MHz (from top left to bottom right). The black to white scales are: for the velocity power from 0 to 200 (m/s)$^2$, for the phase from -180 to +180 degrees, for the magnetic power from 0 to 0.4 G$^2$.

As a consequence, the temporal resolution we get is limited by an observing run of few hours. Nevertheless, it is really useful to perform this analysis since it relates the oscillations to the local phenomena, often considered independent of them. In order to evaluate the contribution of the convection to the signal, a $\ell - \nu$ diagram should be produced in any case, as the distinction between the oscillations and the convection results much easier. In our case the convection contribution is negligible in comparison to the five-minute component.
3. THE RESULTS

The power and V-B phase difference maps have been obtained. Some samples are shown in figure 2 for a selection shown in figure 1. The power spectra for a plage and spot region are also displayed in figure 3. The phase difference changes along the frequency domain and depends strongly on the spatial resolution. Any estimate, averaged in frequency or space, would give misleading values (Ulrich, 1996).

The $\ell - \nu$ diagrams have been produced for more data sets of 256 minutes in January 1998 and using two different software packages to decompose the images into the spherical harmonics: the GRASP managed by the GONG group and the OAC package.

The main differences between the results regard the $\ell$ dependence of the spectra and will be discussed elsewhere. All the diagrams have been corrected for the differential and sync filters applied to the data (figure 4). Nevertheless, some general traits are common:

1) the magnetic diagram does not reproduce the velocity diagram (where the p-modes ridges dominate).
2) the magnetic spectra show two bumps at the five and three-minute bands (figure 5). The first point is confirmed by the local analysis, where the pixel-by-pixel magnetic spectra do not mimic the velocity power, that is the crosstalk can be considered at a lower order of magnitude in the magnetic regions.

The second point is also shown in the local analysis in correspondence of the magnetic structures (see figure 3). We remark that the presence of the three-minute bump in the $\ell - \nu$ magnetic spectra does not imply a global response of the solar cavity (likewise in the p-modes) but can be reproduced by a broad spatial distribution of local sources on the surface (as irregular shaped plages etc.). This can be also seen in the increase of the power in correspondence of the typical spatial scales of the plages and spots present at those days.

![Figure 3. The local magnetic power for a spot region and a plage region of approximately 40" x 40". The five and three-minute bumps are visible.](image)

![Figure 4. The $\ell - \nu$ diagrams for the velocity (top) and longitudinal magnetic field (bottom). They have been obtained from 256 images acquired each minute. The displayed magnetic diagram has been corrected for the differential and sync filters. The software has been provided by M. Oliviero of the OAC.](image)

In order to investigate the general behavior of the power distribution at different spatial scales, the $\ell$ dependence of the magnetic power $\Delta B^2(\ell)$ (hereafter $\Delta B^2$) obtained as the average over the frequency $\nu$ of the $\ell - \nu$ diagram has been performed. We rely on the results shown in figure 6, obtained using the OAC package developed by M. Oliviero.

We adopt the following approach to give a possible interpretation of the results: let us assume that, at the formation layer of the sodium D lines, $\Delta B^2$ is mainly driven by the convective and oscillatory motions. We treat the solar atmosphere as an electric circuit. We used a CR and a RLC to reproduce $\Delta B^2$ as output when $\Delta V^2$ is chosen as input. A dissipative process in a simple resistor circuit can be also used by using the RLC transmission as the resistor's $\ell$ dependence, but its physical interpretation is different. The CR circuit can not explain an increase in the high-$\ell$ values as measured. Indeed, the RLC parameters can be tuned in order to match the results. $A/LC=160000$ ($\ell = 400$) and $R/L=100$ have been introduced to obtain an output the most similar
solution and on the frequency.

The magnetic oscillations have been correlated to the Hα bright points (Moretti et al., 2000). The $\ell - \nu$ diagrams have been obtained using two different software packages. The $\ell - \nu$ diagram for the magnetic signal shows two bumps at the three and five-minute bands. The same bumps are visible in the spot and plage regions with the local analysis. The possible crosstalk between velocity and magnetic field can not reproduce the trait of the spectra.

The $\ell$ dependence of the power spectra have been preliminary interpreted to invoke the presence of a resonant spatial scale peaked at approximately 10000 km.

Higher spatial resolution data are needed to confirm these results.

-REFERENCES


4. CONCLUSIONS

The magnetic oscillations have been detected.

The local analysis suggests a careful interpretation of the results when the data are analyzed to obtain the velocity-magnetic phase difference (V-B) values. In fact, the V-B strongly depends on the spatial re-