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LINE ASYMMETRY AND MAGNETIC FIELDS

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1. Introduction

The measurement of the asymmetries of Fraunhofer lines shows promise as a diagnostic of convection at the surface layers of the sun and stars. We discuss today the observational evidence that line asymmetry, and by inference granular convection, is inhibited by surface magnetism.

2. Origins of Line Asymmetry

St. John, working at the Mt. Wilson 150-ft tower in the first decades in the 1900s, discovered what he termed a 'Limb Effect'; weak to moderate strength Fraunhofer lines display a red shift near the limb, and the amount of this shift is greater for the weaker lines. This 'Limb Effect' can now be understood as a consequence of granulation velocities and as such, is more correctly thought of as a "Centre-disk effect". High resolution spectra at disk centre indicate that the bright granules are rising relative to the darker intergranular space, the material of which is falling. Low resolution spectra, which average over many granules, then possess a brightness weighted blue shift at disk centre which disappears at the limb because the motions are predominately radial.

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A solar granule may be considered as a convection cell. In the centre is a rising column of hot gas moving slowly from deep down, accelerating near the surface to conserve mass, radiating energy and thus cooling, then turning over and flowing down around the cell boundaries. A moderately strong absorption line, such as FeI 5303 Å, is formed throughout the granular layers. As a result the extreme wings of the line, which sense the deepest slow moving layers are relatively undisplaced compared to its main body. Likewise the line core is undisplaced because it is formed well above the granular cell where all outward motion has ceased. A plot of the bisector of such line has a resulting C- shape. Displacement of the extreme of the middle part of the C from its toe can be taken as a measure of convective vigour.

Distortion of the C - shape can arise from line blends, atomic fine structure and an unsymmetric instrument profile (Dravins, et al. 1981). All Fraunhofer lines are in fact blended to some degree. By carefully selecting lines that are minimally blended and then averaging many comparable lines together we obtain a meaningful bisector. Atomic fine structure is avoided by confining ourselves to iron lines. Finally the 1-meter Fourier Transform Spectrometer (FTS) has a demonstrated symmetric profile and exhibits very low noise so far as line bisectors are concerned.

The stochastic nature of granulation is dealt with by spatial averaging. A field of 2 arc-minutes is useful for defining the variation of line asymmetry across the solar disk. Ultimate averaging is the entire disk (10^5-10^6 granules). The internal scatter in full disk FTS bisectors corresponds to about 2 $m.s^{-1}$.

3. Influence of Magnetic Fields on C-shapes

Observational evidence - the 'abnormal granulation' near sunspots - plus theoretical prediction prompts us to investigate how C - shapes are affected by ambient magnetic fields. FTS observations at 2 arc-min resoluion made in plage areas and in quiet areas for comparison at the same limb distance indicate that the bisector amplitude (wing-core) is always reduced in the plage. The only exceptions to this rule occur very near the limb where the amplitude may or may not be reduced.

4. Variability of Line Asymmetry with the Solar Cycle

Two data sets have been examined for the temporal variability of the C - shapes (Livingston, 1982). The profile of FeI 5250.6 Å has been studied for the years 1976-1981 using material acquired with the 13.5-m spectrograph. Because such spectrometer observations are relatively noisy (~ 50 $m.s^{-1}$) many days must be averaged together, but when this is done the position of mid-C relative to the core is seen to have diminished by ~2m Å over these years of rising activity. Beginning in May 1980, FTS profiles became available. The noise in C - shapes from the FTS is much less ~ 5 $m.s^{-1}$. FTS archives for several strong Fe lines indicate a continuation of the trend found with the spectrograph through 1982. During 1983 the C - shapes began to strengthen.

5. Comment on the Pic-du-midi Results

Macris and Rösch (1983) examined the very best white light granulation photographs obtained in recent years at Pic-du-midi. The average size of the granulation was deduced by measuring the average intergranule distance. Tentatively they find that granule size becomes smaller with increasing solar activity.

6. Conclusions

Full disk line asymmetry which is a signature of granular convection has been observed to be diminishing with time until recently when the trend apparently reversed. A comparison of low spatial resolution plage vs quiet regions on the solar disk suggests that surface magnetic fields may inhibit line asymmetry. The average size of granulation likewise is reduced by solar activity according to French observers. We conclude that magnetic fields, expanding over the sun's surface from active regions, may interact globally with the solar granulation to significantly alter the transport of energy through this outermost layer.

References

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DISCUSSION:

BHATTACHARYYA: What is the data from which the French have concluded that the granule size depends on phase in the activity cycle?

LIVINGSTON: They have studied a few (perhaps half a dozen) superior white light photographs taken at Pic-du-midi. Their method involves finding the average distance between granules near disk center in a quiet region.

BALASUBRAMANIAM: Are there any changes in granule size close to spot penumbra?

LIVINGSTON: Although the reference escapes me, I am certain that in the vicinity of active regions, and therefore near penumbrae, one finds "abnormal granulation" which is fragmented compared to normal granulation.

VENKATAKRISHNAN: Can this abnormal granulation be an extension of the inhibition effect in C-shapes due to magnetic fields?

LIVINGSTON: Yes, I assume it is the same mechanism. However, to account for the full disk changes we observe the effect most to be global.

HOWARD: Do the changes in asymmetry seen in integrated light come from the individual plages on the disk?

LIVINGSTON: A good question which I am not prepared to answer quantitatively. As mentioned above, I have been thinking more of a global, rather than active region influence. We do not know that the observed changes in line strength, equivalent width, for example, cannot be caused just by individual plages.