THE CONTINUUM INTENSITY MAGNETIC FIELD RELATION IN SUNSPOT UMBRAE

V. MARTÍNEZ PILLET, M. VÁZQUEZ
Instituto de Astrofísica de Canarias, 38200 La Laguna, Tenerife, Spain

ABSTRACT   The *local* relation between the temperature and the magnetic field in sunspot umbrae is studied. Sunspots with different sizes have been studied and we found a linear relation between temperature and the square of the magnetic field. We have found also a dependence between the minimum continuum intensity and the size of the spot.

INTRODUCTION

The observations were carried out at the Gregory Coudé Telescope of the Observatorio del Teide (Canary Islands) at moments of negligible instrumental polarization. Information about the temperature is extracted from the observed continuum intensity. The scaling relation between Stokes V and the continuum intensity is used to estimate the stray-light contamination (for a detail discussion, see Martínez Pillet and Vázquez, 1993). The magnetic field is deduced from the peak separation of the Stokes V profiles. Lines with different excitation potentials have been used.

The observed local relation can be adapted to the equations describing sunspot horizontal force balance. The commonly accepted value for the Wilson depression (600 km) suggests that the tension forces are as important as the magnetic pressure in defining horizontal equilibrium. The local relation found holds for spatial scales larger than 1″. Our observations do not reach the level of the umbral fine structure. However, clear insights of unresolved hot *magnetized* regions have been observed.

Our study provides valuable clues pointing to a dependence of continuum intensity with sunspot area. Smaller spots are seen to be brighter than bigger ones. The scaling relation between Stokes V and the continuum intensity also provides indirect support for our findings of a dependence between brightness and sunspot size.

RESULTS

1) At those heights where the visible continuum and spectral lines are formed, there is a local relation between continuum intensity and magnetic field. A similar relation has been found in the infrared by Kopp and Rabin (1992) and Solanki *et al.* (1993).

2) This result can be seen as a linear relation between temperature and the square of the magnetic field (see Figure 1). Following Martínez Pillet and Vázquez (1991), we deduced values for the Wilson depression about 600 Km which require magnetic tension forces inside umbrae similar to the magnetic pressure contribution.
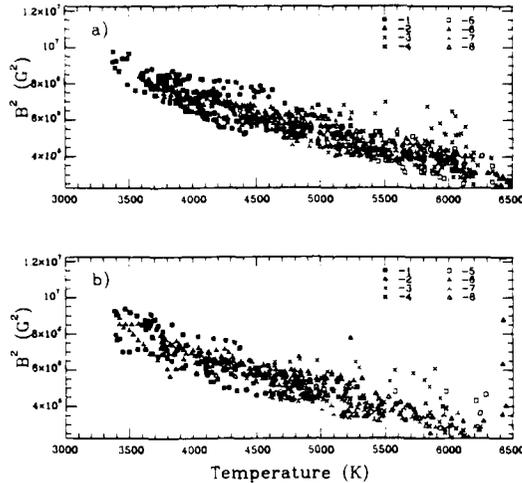

Fig. 1.   Temperature versus magnetic field square for all the observed spots. Each symbol refers to a particular spot. Cases 1 and 6 are large spots (umbral radius ≈ 10″). 3, 4, 7 and 8 are medium size spots (umbral radius ≈ 5″) and 2 and 5 are small spots (umbral radius ≈ 2″). The data are corrected for stray-light. a) Results for the FeI 6302 Å line. b) Results for the TiI 6064 Å line.

3) We have found evidence to support the existence of hot magnetic regions inside some umbrae. This result is deduced from the strong signals seen in the Stokes V profile of the FeII 6149 Å line. These signals are not explained by penumbral stray-light which would produce a much smaller contribution.

4) In Figure 2.a we represent the minimum continuum intensity versus the umbral area. Smaller spots are hotter than larger ones. This difference in brightness between spots is also seen when we use A_v as a measure of the continuum intensity which is much less sensitive to stray-light (Figure 2.b). A_v is the integrated absolute value Stokes V signal normalized to the photospheric continuum intensity. It can be seen that, for strong fields, this parameter is given approximately by:

$$A_v \propto \frac{I_c^{spot}}{I_c^{ph}} \eta_o \cos \gamma,$$

where η_o is the line center opacity ratio, γ the magnetic field angle with respect to the line of sight and the I_c's are the continuum intensities of the spot and photosphere. For the line FeI 6302 Å, A_v is not sensitive to changes in η_o due to changes in temperature. Thus, the difference observed in Figure 2.b can only

be explained by an intrinsic difference in the real continuum intensities of the associated spots.
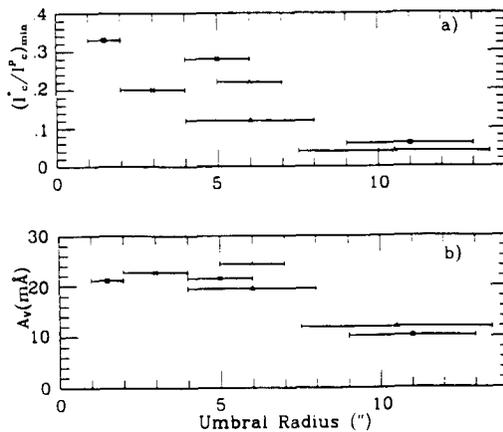

Fig. 2.   a) The dependence of the minimum continuum intensity with the average spot radius. The error-bars represent the maximum and minimum umbral sizes observed for each spot. The symbols refer to the same spots as in Fig. 1. The continuum intensities are corrected for stray-light. Yet there is still a clear dependence between both magnitudes. b) The average value of the Stokes V area (FeI 6302 Å) for each spot against umbral size. The factor 2 between the signals for big and small spots can only be explained as due to intrinsically lower continuum intensities for big spots.

ACKNOWLEDGEMENTS

REFERENCES

Kopp, G., and Rabin, D.: 1992, *Solar Phys.*, **141**, 253
Martínez Pillet, V., and Vázquez, M.: 1990 Ap&SS **170**, 75
Martínez Pillet, V., and Vázquez, M.: 1993 *Astr. Ap.*, , in press
Solanki, S.K., Walther, U., and Livingston, W.: 1993, these proceedings