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Spectral signature of uncombed penumbral magnetic fields

Comment

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Abstract. The conservation of magnetic flux demands a magnetic field fine structure as small as 15 km to explain the net circular polarization observed in penumbrae (Sánchez Almeida 1998). A recent work by Martínez Pillet (2000) claims that modeling penumbrae as a collection of fluxtubes 100 km wide suffices. We identify several shortcomings of such modeling so that it is presently unclear whether it really contradicts the former conclusion.

Key words. Sun: magnetic fields – sunspots

The geometrical scales that characterize the magnetic fields in sunspot penumbrae determine which physical processes are relevant, constrain the observational possibilities, and define the techniques needed to single out individual penumbral structures. Since the complexity of the penumbra is probably representative of all solar magnetic structures, it provides insight of general application. These considerations illustrate the clear, direct and varied scientific interest of assigning a geometrical scale to the penumbral unresolved structure.

Sánchez Almeida (1998; SA) assigned such scale by matching the gradients of magnetic field inclination deduced from Net Circular Polarization[1] (NCP) and from magnetic flux conservation (actually, from the pixel-to-pixel variations of the horizontal magnetic field plus application of $\nabla \cdot \mathbf{B} = 0$; $\mathbf{B}$ stands for the observed vector magnetic field). Based on order of magnitude arguments, he concludes that any model penumbra able to reproduce these two observables must possess irregularities across field lines smaller than some 15 km. The only essentials to reach such conclusion are: a) a random distribution of magnetic fibrils within each resolution element, b) mass flows aligned with the magnetic field and, c) a preferred orientation of all field lines within the resolution element. Finding one counterexample would invalidate SA's conclusion that penumbrae must be structured on scales of a few kilometers in order to produce what we observe.

Martínez Pillet (2000; MP) has recently modeled penumbrae as an array of horizontal fluxtubes embedded in an inclined magnetic field and carrying mass flows. With the diameter of the individual fluxtubes set to 100 km, he concludes that the "gradients are found to be compatible with those obtained from the null divergence condition and those derived from observations of net circular polarization". One may easily interpret this conclusion as if the counterexample mentioned above has been found. In view of the implications of such finding, we feel compelled to clarify that this is not the case. Despite their key role, several ingredients of MP's modeling are not treated consistently in the simulation.

First, MP employs two different models to synthesize the two different observables whereas a single atmosphere should be used. Specifically, the schematic model where the pixel-to-pixel fluctuations are evaluated does not necessarily reproduce the observed NCP. The absolute value of the vertical gradient of magnetic field is constrained, but this restriction does not determine the NCP of a fluxtube (see Eqs. (1) and (4) in SA). Second, randomness of the magnetic field distribution is achieved by considering a collection of fluxtubes placed at random heights in the atmosphere, without accounting for variations of the number of fluxtubes per resolution element. This would further increase the pixel-to-pixel fluctuations produced by the array of fluxtubes. Finally, MP's modeling generates a pixel-to-pixel fluctuation that is three times too large compared with the observations. This mismatch is neglected although, assuming that everything else were correct, it would indicate that some ten times more fluxtubes per resolution element are needed to reproduce the observations. We mention this fact to emphasize how the error budget of any future modeling is critical to offer clear conclusions.

In short, SA's picture in which penumbrae must contain a rich optically-thin fine structure still stands.

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[1] The NCP is the mean circular polarization produced by a spectral line.

References

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