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NEW CALIBRATION PARAMETER FOR OBSERVATIONS OF TRANSVERSE SOLAR MAGNETIC FIELDS IN THE Fe I 5324.19 Å LINE

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ABSTRACT Adopting the computational model of papers I and II (Song *et al.* 1990, 1992) we have found that for a better fit of the center of the Fe I 5324.19 Å line, the effect of turbulent Doppler broadening has to be taken into account. Through theoretical and numerical analysis we conclude that the square root of the modulus of Stokes Q and U is an appropiate observational parameter to represent the transverse magnetic field, since it is approximately linearly proportional to the strength of the transverse magnetic field for suitable positions of the filter passband.

INTRODUCTION

One of the main obstacles for the calibration of observations of the transverse magnetic field is that the Stokes Q and U parameters are not linearly proportional to the strength of the transverse magnetic field. Thus it is hard to specify quantitatively the sensitivities at different distances from the line center, and the interpretation can only be based on calibration curves without specific calibration coefficients (Ai *et al.* 1982). This has long been a troubling problem for the theoretical calibration of observations of the transverse magnetic field. Accordingly there is a great need to find a new parameter with a well-defined linear dependence on the magnetic field.

NUMERICAL TREATMENT

The parameter that we are looking for is expected to have both good sensitivity at a certain distance from line center and a linear dependence on the magnetic field. Before we can test the behavior of various possible parameter choices we have to have a model that can reproduce the observed line profile.

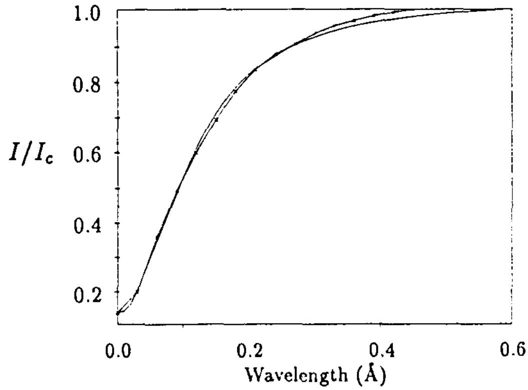

Fig. 1. Intensity I of the Fe I 5324.19 Å line normalized to the intensity I_c at 0.60 Å from line center. Crosses: The profile observed at Sacramento Peak Observatory. Dots: Computed profile.

Our computations indicate (for details, see Ai *et al.* 1982, Song *et al.* 1990) that the Stokes I profile of the Fe I 5324.19 Å line can be fitted very well with the observed one (Beckers *et al.*, 1976, only the red wing is considered), provided that the Doppler velocity of the VAL model atmosphere (Vernazza, 1976) is reduced by a factor of 72 % (cf. Solanki *et al.* 1988), and the oscillator strength is 0.08, very similar to that of Ai (1982) (see Fig. 1).

THE RESULTS OF THE CALIBRATION

The profile of the filter is

$$\begin{aligned} T(\lambda, \lambda_0) = &\cos^2[\pi(\lambda - \lambda_0)/0.15 + \lambda_0/0.30] \cos^2[\pi(\lambda - \lambda_0)/0.30 + \lambda_0/0.60] \\ &\cos^2[\pi(\lambda - \lambda_0)/0.60 + \lambda_0/1.20] \cos^2[\pi(\lambda - \lambda_0)/1.20 + \lambda_0/2.40] \\ &\cos^4[\pi(\lambda - \lambda_0)/1.20] . \end{aligned} \tag{1}$$

The profiles of the Stokes parameters transmitted by the filter are given by

$$S^*(\lambda') = \left(\int_{-2\Delta\lambda}^{2\Delta\lambda} T(\lambda, \lambda') S(\lambda) \, d\lambda \right) \Big/ \left(\int_{-2\Delta\lambda}^{2\Delta\lambda} T(\lambda, \lambda') \, d\lambda \right) . \tag{2}$$

$S(\lambda)$ represents a Stokes profile before reaching the filter.

As concerns the transverse magnetic field, we have

$$Q = -\frac{1}{4}(\Delta\lambda_H)^2 \left[\frac{\partial^2 I}{\partial \lambda^2} + \frac{1}{12}(\Delta\lambda_H)^2 \frac{\partial^4 I}{\partial \lambda^4} + \ldots \right] \tag{3}$$

(for details, see Stenflo, 1985). From the above it follows that $Q \sim B^2$ close to the line center in the case of weak magnetic fields.

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The results of the computations (the parameters are set as in Song *et al.*, 1990, the steps and limits as in Song *et al.* 1992) are that if we adopt as the calibration parameter $(Q^2+U^2)^{1/4}$, then the region around the center of the Fe I 5324.19 Å line may be divided into three different regimes:

1. 0.00–0.01 Å. In this range the Q and U parameters depend on the magnetic field exactly as described by Eq. (3). $(Q^2+U^2)^{1/4}$ is linearly proportional to the field strength when the field is weak. For stronger fields the curves turn upwards due to the higher-order terms in Eq. (3).
2. Within the 0.02–0.03 Å range the relation between $(Q^2+U^2)^{1/4}$ and field strength shows the smallest nonlinearities over the whole field-strength range of 0–2 kG. We may therefore regard $(Q^2+U^2)^{1/4}$ to be linearly dependent on field strength even when the field is fairly strong.
3. Beyond about 0.04 Å from line center $(Q^2+U^2)^{1/4}$ is linearly proportional to the field strength when the field is weak. For stronger fields the curves turn downwards in disagreement with Eq. (3).

In summary, from considerations of sensitivity and linearity (Song *et al.* 1992) we have found that the best place to position the filter passband is in the range 0.02–0.03 Å from line center.

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