J. Astrophys. Astr. (2005) **26,** 435–445

Small-scale Magnetic Field Diagnostics outside Sunspots: Comparison of Different Methods

D. N. Rachkovsky[1], T. T. Tsap[1] & V. G. Lozitsky[2]
[1]*Crimean Astrophysical Observatory, Nauchny, Crimea, UA-98409, Ukraine.*
[2]*Kyiv University Astronomical Observatory, Observatorna St. 3, Kyiv, UA-04053, Ukraine.*
e-mail: lozitsky@observ.univ.kiev.au

Received 2004 December 28; accepted 2005 November 28

Abstract. We analyse different observational data related to the problem of intrinsic magnetic field strength in small-scale fluxtubes outside sunspots. We conclude that the kG range of fluxtube fields follows from not only classical line ratio method, but also from other old and new techniques. For the quiet regions on the Sun, the most probable mode of such fields has a magnetic field strength of 1.2–1.5 kG assuming the rectangular field profile. To best interpret the observations, a weak background field between fluxtubes should be assumed, and its magnetic field strength is expected to increase with the filling factor of fluxtubes. The alternative point of view about subkilogauss fluxtube fields is critically examined, and possible sources of different conclusions are presented.

Key words. Sun—magnetic fluxtubes—kG magnetic fields.

1. Introduction

Recently Zirin & Cameron (2002) published a very interesting paper with new observational data concerning the problem of intrinsic magnetic field strength of non-spot regions. These authors proposed a new method of magnetic field diagnostics for regions of weak measured fields which is similar to the line ratio technique proposed by Stenflo (1973). The main conclusion of Zirin & Cameron (2002) is that 'the invisible kilogauss fields postulated by Stenflo do not exist in these weak field elements'. Note that this conclusion contradicts not only J. O. Stenflo, but also many other investigators in the field of magnetography. So, we have at hand, a very interesting problem, which would influence our understanding of the physical nature of the small-scale magnetic fields on the Sun.

Detailed magnetic characteristics of the small-scale magnetic elements are practically unknown due to essential problems with the magnetic field measurements in very inhomogeneous solar plasma. This problem has been discussed by many authors (Severny 1964, 1965, 1966, 1967; Steshenko 1967; Howard & Stenflo 1972; Stenflo 1973; Frazier & Stenflo 1978; Wiehr 1978; Koutchmy & Stellmacher 1978; Lozitsky 1980; Rachkovsky & Tsap 1985; Staude & Hoffman 1988; Carroll & Staude 2001, etc.).

Firstly, the most important observational clue on the existence of the spatially unresolved magnetic fields with kG fields was discovered with a Babcock (1953) type solar magnetograph, in two lines of the same multiplet of FeI, 5247.1 and 5250.2 Å, which have practically equal levels of formation and temperature sensitivity, but different Lande factors g, 2.0 and 3.0, respectively (Stenflo 1973). Theoretically, in case of subkilogauss magnetic fields these lines must give practically the same measured field values, as manifested by the longitudinal magnetic field $\boldsymbol{B}_{\parallel}$ in the solar atmosphere. In practice however, the first line gives, as a rule, about 15–20% more strong field than the second one. In addition, the line ratio $\boldsymbol{B}_{\parallel}(5247)/\boldsymbol{B}_{\parallel}(5250)$ was observed to increase from line center to its wing. On the basis of calculations, Stenflo (1973) showed that this anomalous behaviour of the line ratio indicates the intrinsic magnetic field strength to be in the range 1.1–2.3 kG. Although he observed with spatial resolution ~ 1700 km in quiet regions on the Sun, he postulated the existence of the invisible magnetic flux tubes with probable diameters 100–300 km.

This was a very courageous idea, which was proposed in the same time when the problems of magnetographic signal calibration were not fully resolved. In particular, in the same year Gopasyuk *et al.* (1973) published interesting results about magnetic field comparison in different spectral lines. It was shown for about ten lines, that, in general, measured field $\boldsymbol{B}_{\parallel}$ decreased with the magnetic sensitivity factor $g\lambda^2$. As pointed out later by Lozitsky (1979, 1980), the observed peculiarities of this dependence can not be explained in terms of spatially unresolved magnetic fields with intrinsic strengths of 1–2 kG. An alternative suggestion was that this dependence had an instrumental origin.

In addition, Severny (1967) obtained the essential differences between theoretical and experimental calibration curves of the solar magnetograph, using the sunspots as objects on the Sun with well detectable magnetic field. Further, similar unexplained differences were obtained for laboratory calibration of the magnetograph, for the case of a known homogeneous field. This raises the question: if one cannot measure the *homogeneous* fields (in the laboratory) how can we measure the *inhomogeneous* fields (on the Sun)?

For a way out of the situation, the data of full Stokes profiles were needed – similar to Stokesmeter (Harvey *et al.* 1972), or spectral data obtained with a polarization analyser (Kouchmy & Stellmacher 1978; Lozitsky 1980), or Fourier transform spectrometer (Stenflo *et al.* 1984). They confirmed, in particular, that line ratio differences are not instrumental effects. Practically the same dependence of $\boldsymbol{B}_{\parallel}$ versus $g\lambda^2$, as obtained by Gopasyuk *et al.* (1973), was found by Lozitsky (1979, 1980) using the spectral data based on Stokes I profiles of about ten lines. Lozitska *et al.* (1982) showed that empirical calibration curves of the solar magnetograph obtained by Severny (1967) may be explained by more narrow spectral lines of HgI in laboratory spectra, and also by the increase in half-widths that occurs due to increasing of the total pressure (gas + magnetic) in a glass balloon. So, some of named problems were partly resolved, and it supports indirectly the main conclusion about the reality of the strong unresolved magnetic fields on the Sun. In addition, a very wide analysis of the statistical properties of the Stokes I and V line profiles of 400 unblended FeI lines showed that the field strength in network and plages is in the range 1.26–1.72 kG, and filling factor is from 3% to about 15% (Solanki & Stenflo 1984).

In this paper, we analyse the recent results concerned with this problem and consider the most reliable and direct data related to intrinsic magnetic field range in non-spot and non-flare regions.

2. Line ratio method

The basic idea of all methods for unresolved magnetic field diagnostics is the following: if one cannot resolve the superfine structures spatially one could 'resolve' spectrally, using an instrument with high spectral resolution and several spectral lines with different Lande factors preferably large in value. In case of an inhomogeneous field (like any fluxtubes with strong magnetic field and weak background field) we should observe the partial spectral polarized contributions in the total observed profile of the line. The position on the line profile of the contributions of different field strengths would depend on the Zeeman splitting rule.

This approach needs the Stokes profiles. On the other hand, the observational data for one point in line wing (like classical magnetograph) or integrated data for wide spectral interval (from line center to continuum – as in filter magnetograph) are practically useless for this goal. This explains why many authors had used several narrow positions of the exit slits of magnetograph in line profiles (Stenflo 1973; Frazier & Stenflo 1975; Wiehr 1978; Rachkovsky & Tsap 1985, etc.).

In the present work we continue to study the small-scale structure of the non-spots magnetic fields using new observational data and new theoretical calculations for these observations. Below we calculate the theoretical diagnostic dependences more exactly than in earlier published papers by Rachkovsky & Tsap (1985), and also Lozitsky & Tsap (1989).

We present here the results of observations made in good seeing near disk center on 24 April 1991 with double Crimean magnetograph (Kotov *et al.* 1982), in FeI 5247.1 and 5250.2 lines. The spectral resolution was 1×2 arc sec, scanned area – 160×160 arc sec related to a quiet region. Three sizes of the exit slits were used: 15–40, 35–60 and 55–80 mÅ from the line center. Magnetograph signals were calibrated and compared in both lines similar to procedure described earlier in detail by Rachkovsky & Tsap (1985).

Theoretical line ratio dependences were calculated using the solutions for the radiative transfer equations in magnetoactive medium (Rachkovsky 1963)

$$\cos\theta \frac{I_{\pm}(\tau,\theta)}{d\tau} = (1+\eta_0\sigma_{\pm})I_{\pm} - (1-\varepsilon)\eta_0 \frac{3}{8\pi(k_l+k_r+k_p)} \int\limits_{4\pi} (\sigma_+ I_+ + \sigma - I_-)d\omega$$
$$- \frac{1}{2}(1-\varepsilon\eta_0\sigma_{\pm})(1+\beta\tau)B_0, \qquad (1)$$

where η_0 is the ratio of line-to-continuum absorption at line center, $\sigma_{\pm}$ are absorption coefficients in spectral line for mutually orthogonal polarizations '$\pm$', ε is probability of full quantum absorption, k_l, k_r, k_p – absorption coefficients for left-, right-, and linear-polarized radiation, β is coefficient of the linear approximation for source function versus optical depth τ in spectral continuum, and B_0 is the Planck's function.

Mathematical solution for equation (1) depends on the parameter α of Voigt function, i.e., the ratio of damping to Doppler width $\Delta\lambda_D$. These parameters were determined using the observed Stokes I profiles of lines. So long as observed profiles for FeI 5250.2 and FeI 5247.1 lines were found practically the same, line FeI 5250.2 only was used as experimental sample to the theoretical fit (Fig. 1).

One can see from Fig. 1 that theoretical profile (dashed) satisfy the observations (solid line) very well. The following parameters were used: $\eta_0 = 10$, $\varepsilon = 0.05$, $\beta = 2$,

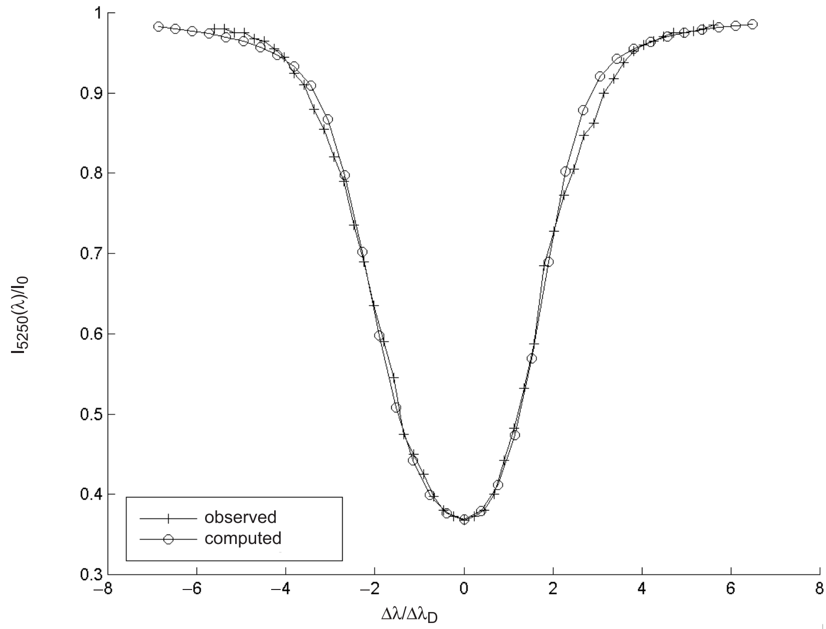

Figure 1. Comparison of the observed and computed profiles for FeI 5250.2 line.

$\alpha = 0.35$, $\Delta\lambda_D = 25\,\mathrm{m\AA}$. The parameter ν is the wavelength displacement from the line center in units of the Doppler width, i.e., $\nu = \Delta\lambda/\Delta\lambda_D$.

Similar to our previous work (Rachkovsky & Tsap 1985), calculations were made for two-component model, according to which the small-scale fluxtubes with strong field B_f are embedded in a more weak background field B_b. Also, we assumed that magnetic field strength was constant in the height range of the line formation in the solar atmosphere, and within the cross-section of each fluxtube (rectangular field profile). In this case,

$$k = \frac{S_b \times V_1(B_b) + S_f \times V_1(B_f)}{S_b \times V_2(B_b) + S_f \times V_2(B_f)} = \frac{1 + x(V_1(B_f)/V_1(B_b))}{1 + x(V_2(B_f)/V_2(B_b))}, \tag{2}$$

where k is the magnetographic signal ratio for FeI 5250 and FeI 5247, V_1 and V_2 are Stokes V parameters for these lines, respectively, S_b and S_f are relative areas of the weak and strong field, and $x = S_b/S_f$.

The results are given in Fig. 2 and Table 1. The data of the old observations for 1978 are presented as well. We can see all observational data including Stenflo's (1973) measurements are in good agreement.

As it follows from comparison of the observations and theory, all presented observational data need the magnetic fields of *kilogauss range*, namely $B_f = 1100$–1500 G. The probable diameter of the fluxtube was found close to 120 km. As to background field, our calculations do not allow to determine its true strength and possible structure. On the other hand, it is important to note that obtained data strongly indicate

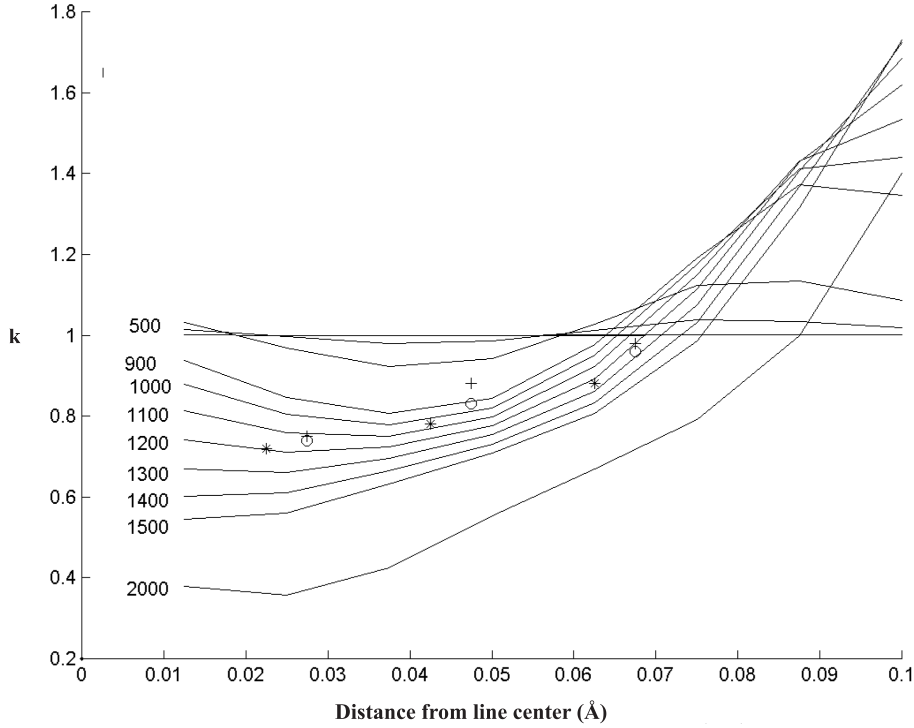

Figure 2. Observed and theoretical dependences for k parameter vs. distance from line center: $+$ – observational data by Stenflo (1973), * and $^\circ$ – observational data of the present work obtained in 1978 and 1991, respectively, solid curves – theoretical dependences calculated for $\Delta\lambda_D = 22$ mÅ, $\eta_0 = 10$, $\varepsilon = 0.05$, $\beta = 2$, $a = 0.35$ and different magnetic field strengths in the magnetic fluxtubes indicated in the figure.

Table 1. Comparison of the observations and calculations for different parameters of the theoretical model.

Exit slit sizes, mÅ	Observations of 1978	Observations of 1991	Model: $\Delta\lambda_D = 25$ mÅ, $x = \infty$, $B_f = 1200$ G	Model: $\Delta\lambda_D = 22$ mÅ, $x = 0.012$, $B_f = 1300$ G	Model: $\Delta\lambda_D = 22$ mÅ, $x = 0.006$, $B_f = 1500$ G
15–40	0.74	0.75	0.74	0.75	0.74
35–60	0.83	0.88	0.78	0.82	0.81
55–80	0.96	0.98	0.95	0.97	0.92

the existence of the background field. Earlier, it was found that B_f should increase with the filling factor α of fluxtubes, and $B_b/\alpha \approx 1$ kG (Lozitsky & Dolgopolov 1983; Lozitsky & Tsap 1989).

Also, calculations show that for $x = \infty$ the best fit with observations correspond to $\Delta\lambda_D = 25$ mÅ, that gives the effective temperature $T \approx 6000 \pm 600$ K. One cannot obtain a good agreement between observations and theory for other values of $\Delta\lambda_D$.

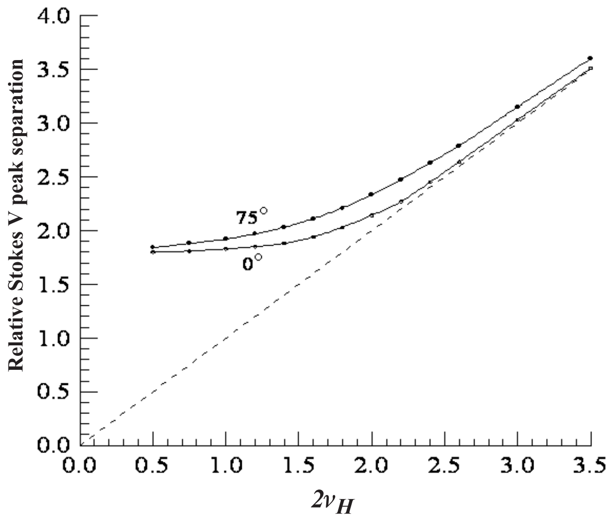

Figure 3. Theoretical dependences of the relative splitting $\Delta\lambda_V/\Delta\lambda_D$ of the Stokes V peaks vs. double relative Zeeman splitting $2\nu_H = 2\Delta\lambda_H/\Delta\lambda_D$ for two angles γ (0° and 75°) between the field line and the line of sight (Lozitska & Lozitsky 1994). It is assumed that $\eta_0 = 0.5$.

So, we can conclude, that line ratio method indicates strongly to the reality of the small-scale magnetic fluxtubes with kG strengths. On the other hand, new observations and theoretical calculations are needed to determine their more reliable characteristics using new methods with more direct Stokes profile recording, and higher spatial and temporal resolution.

3. Stokes *V* peak separation

The particular drawback of FeI 5250 and FeI 5247 lines is their relatively high temperature sensitivity (Harvey and Livingston 1969; Staude 1970a, b). Lozitska & Lozitsky (1994) have shown that the temperature sensitivity of the pair 5250.2/5247.1 is not an obstacle for reliable magnetic field measurements if we do not use the Stokes V amplitude (such as in a solar magnetograph), but the Stokes V peak separation, $\Delta\lambda_V$. Also, the Stokes V peak half-width, $\Delta\lambda_{1/2,V}$, and the Stokes I half-width, $\Delta\lambda_{1/2,I}$, could be successfully used for small-scale magnetic field diagnostics.

According to calculations, the Stokes V peak separation, $\Delta\lambda_V$, is a very sensitive parameter for Zeeman splitting measurements, especially in case $\Delta\lambda_V/\Delta\lambda_D \geq 2$, or $\Delta\lambda_H \geq \Delta\lambda_D$, where $\Delta\lambda_H$ is the Zeeman splitting (Fig. 3).

As it follows from Fig. 3, for $0.5 < \nu_H < 1.5$ the ratio $\Delta\lambda_V/\Delta\lambda_D$ is a nonlinear function of ν_H. In this interval the field strength cannot be determined directly from the splitting $\Delta\lambda_V$, but from a comparative study of the splitting of lines with different Lande factors.

Corresponding determinations of the value of B is difficult, because $\Delta\lambda_V/\Delta\lambda_D$ depends not only on the parameter ν_H, but also on γ. The latter dependence becomes stronger when η_0 increases. Since there are actually two unknown quantities (B and γ), additional data should be used. Such data can be the half-widths of the V-peaks,

$\Delta\lambda_{1/2,V}$, which also depend on ν_H. This parameter also depends on both ν_H (i.e., B) and γ.

The observations can be interpreted assuming $\nu_H(5250) = 1.5\nu_H(5247)$, while H(5250) = H(5247) and $\gamma(5250) = \gamma(5247)$. This is the idea (firstly proposed by Lozitska & Lozitsky (1994)) behind the line-ratio technique.

On the base of such study of the Stokes V peak peculiarities, the small-scale structure of the solar flares was investigated (Lozitsky *et al.* 1999, 2000). Below we use this method to the non-flare magnetic field diagnostics.

First observational results suitable to this method were obtained by Stenflo *et al.* (1987). In a faculae at the center of the disk $\Delta\lambda_{1/2,\,I} = 87$ mÅ for FeI 5247 line and 88 mÅ for FeI 5250. On the other hand, for the Stokes V separation, $\Delta\lambda_V$, more essential differences were found, namely 81 mÅ for first line and 100 mÅ for the second. Notice if the magnetic field is really weak and the lines are formed in the undisturbed atmosphere, then we should find $\Delta\lambda_V = 72$ mÅ and $\Delta\lambda_{1/2,\,I} = 84$ mÅ *for both lines* (Lozitska & Lozitsky 1994).

Above pointed relations for the faculae $\Delta\lambda_{1/2,\,I}(5250) \approx \Delta\lambda_{1/2,\,I}(5247)$, but $\Delta\lambda_V(5250) = 1.23\Delta\lambda_V(5247)$ present a very strong and direct evidence to the kG fields in the solar faculae. As it follows from calculations, more exact value for this case corresponds to $B_f = 1.28 \pm 0.03$ kG. This value agrees with magnetic field strengths 1.26–1.72 kG obtained by Solanki and Stenflo (1984) from regression coefficients for about 400 unblended FeI lines.

Similar evidences to the strong non-spot field were obtained also with Echelle spectrograph of the horizontal solar telescope of the Kyiv Shevchenko National University (Kurochka *et al.* 1980). In particular, for the places of photosphere in active region AR 19864 of 12 October 1977 the following Stokes V peak ratio was found: $\Delta\lambda_V(5250)/\Delta\lambda_V(5247) = 1.20$. If we add to these data, the necessary data about $\Delta\lambda_{1/2,V}$ and $\Delta\lambda_{1/2,\,I}$, then we obtain $B_f = 1.41 \pm 0.10$ kG.

Similar values of the non-spot fields were obtained with the same instrument using Stokes V separation method for other dates as well. For instance, for the 2B flare of 16 June 1989, the fluxtube magnetic field strength was found to be about 1.1 kG at the start of the flare and during the flash phase, 1.55 kG during the peak, and 1.38 kG 16 min after the peak (Lozitska & Lozitsky 1994). For the 1N solar flare of 26 June 1981, the value of $B_f \approx 1.8$ kG was obtained for the flare peak using the observations in FeI 6301.5 and 6302.5 lines (Lozitsky *et al.* 1999).

During 2000–2004 new observations of the non-spot fields were carried out with named Echelle spectrograph in Kyiv (Kurochka *et al.* 1980), and these observations allow to make the following general conclusion. In each case when the Zeeman splitting is reliably measured on the spectrogram ($\boldsymbol{B}_{\parallel} > 100$ G) we found the effects in Stokes V separation of the FeI 5250 and 5247 lines which is similar to the one discovered earlier by Stenflo *et al.* (1987). So, these new data independently confirm earlier observations and strongly indicate to the reality of the spatially unresolved magnetic fields of kG range.

4. Method by Zirin and Cameron

This method was proposed for observations with the Big Bear Spectrovideomagnetograph (Zirin & Cameron 2002). In this instrument, signal of the circular polarization V is integrated on spectral intervals $\pm(0 \div 150)$ mÅ relatively the line center, which for a line like FeI 5250.2 correspond to whole spectral line – from line core to its far wings. Normalized magnetographic signal in line λ_1, M_{λ_1}, could be presented via formula

$$M_{\lambda_1} = \int_{\lambda_l}^{\lambda_v=0} V/g_{\lambda_1} d\lambda - \int_{\lambda_{V=0}}^{\lambda_r} V/g_{\lambda_1} d\lambda, \tag{3}$$

where first integral is calculated in spectral interval from $-150\,$mÅ to the Stokes V zero crossing point, and second one – from named point to $+150\,$mÅ.

After some mathematical transformations, named authors obtained

$$M = 2\alpha_m z \lambda_0^2 B D_m, \tag{4}$$

where α_m is possible filling factor for magnetic component, z – some constant, and D_m – the line depth in the magnetic component for the Stokes I.

Such presented value $\boldsymbol{M}$ was compared for FeI 5247 and 5250 lines, and obtained results are given in Fig. 3 in paper by Zirin & Cameron (2002). From this figure it follows that values $\boldsymbol{M}_{5247}$ and $\boldsymbol{M}_{5250}$ correlate very closely in strength range $-50\,\mathrm{G} < \boldsymbol{M} < 100\,\mathrm{G}$, and $\boldsymbol{M}_{5247}/\boldsymbol{M}_{5250} \approx 1$. So, there was no evidence of the differences of 10–30%, which were discovered earlier by Stenflo (1973) and other authors.

Zirin & Cameron (2002) have considered once more diagnostic dependence (see Fig. 4 in named article): difference $\boldsymbol{V}_{5250}/3 - \boldsymbol{V}_{5247}/2$ versus distance from line center $\Delta\lambda$. Theoretically, for really weak or moderate magnetic field ($<$ 200–300 G) this difference should be equal to zero, whereas for strong fields ($>$ 1 kG) – far from zero. Named authors obtained some non-zero difference from their observations, but it was about three times less than for kilogauss fields.

For a critical analysis of Zirin & Cameron (2002), we should firstly point out that one cannot fully exclude some non-typical case of the difference between FeI 5247 and 5250. For example, in the paper by Cerdena *et al.* (2003) the following line ratio for inter-network magnetic fields was obtained: $\boldsymbol{B}_{\mathrm{eff}}(630.15)/\boldsymbol{B}_{\mathrm{eff}}(630.25) = 1.25 \pm 0.14$. This line ratio indicates the true magnetic field of $B_f = 1.25$–$1.5\,$kG in the small-scale unresolved fluxtubes. Note this result bases on observations with very high spatial resolution (0.2 ars sec, or 150 km), which were interpreted with a method like line ratio technique. Maybe, for any local places on the Sun the line ratio could be very different from the majority cases. For example, Lozitsky & Lozitsky (2002) discovered a practically opposite ratio for regions of flares: $\boldsymbol{B}_{\mathrm{eff}}(630.15)/\boldsymbol{B}_{\mathrm{eff}}(630.25) = 0.8$–$1.1$. Perhaps, similar non-typical (but non-flare) cases are present in the observational statistics in Zirin & Cameron (2002).

On the other hand, we can point to another, systematic source of the alternative conclusion made by these authors. As it was pointed above, in a case of very wide integrating intervals for Stokes V signal, the useful information about small-scale fields should be lost. To preserve this information, an enough high spectral resolution is needed. In fact, as it follows from our calculations, theoretical dependencies for line ratio $\boldsymbol{k}$ (see Fig. 2) have the following peculiarities: $\boldsymbol{k} < 1$ for $\Delta\lambda <$ 70–90 mÅ, but $\boldsymbol{k} > 1$ for $\Delta\lambda >$ 70–90 mÅ. Naturally, we can expect $\boldsymbol{k} \approx 1$ in more wide spectral interval $\Delta\lambda =$ 0–150 mÅ (as in BBSO instrument). So obtained by Zirin & Cameron's (2002) ratio $\boldsymbol{M}_{5247}/\boldsymbol{M}_{5250} \approx 1$ has a very natural explanation, which *does not exclude the existence of the small-scale magnetic fluxtubes with kG fields*.

5. Discussion

It will be useful to remember that the first magnetographic observations by Severny (1967) discovered *non-constant* line-to-line strength ratio for non-spot regions. He obtained the *various* ratio $\boldsymbol{B}_{\|}(6103)/\boldsymbol{B}_{\|}(5250)$ including the cases when, for example, $\boldsymbol{B}_{\|}(6103)/\boldsymbol{B}_{\|}(5250) \approx 0$, and $\boldsymbol{B}_{\|}(6103)/\boldsymbol{B}_{\|}(5250) \approx 1$. Severny (1967) interpreted these results as a manifestation of the very inhomogeneous magnetic field structure in vertical direction.

Later, *constancy* of the line-to-line strength ratio was measured by Harvey & Livingston (1969). They discovered practically constant line ratio $\boldsymbol{B}_{\|}(\lambda_i)/\boldsymbol{B}_{\|}(\lambda_j)$ from magnetographic measurements in several spectral lines (λ_i and λ_j) including well known lines as FeI 5250 and 5233. For example, the ratios of $\boldsymbol{B}_{\|}(5233)/\boldsymbol{B}_{\|}(5250) \approx 3$ were found. Exactly, the constancy of these line ratio was measured in a limited field range only, about $\boldsymbol{B}_{\|} < 100 - 200$ G. This result was confirmed late by Stenflo (1973) and Gopasyuk *et al.* (1973).

Stenflo (1975) reasonably pointed that constancy of the line ratio presents a very important information about physical characteristics of the spatially unresolved fluxtubes. So long as $\boldsymbol{B}_{\|}(\lambda_i)/\boldsymbol{B}_{\|}(\lambda_j) \approx$ const, all fluxtubes should have *universal and homogeneous properties.* In particular, all fluxtubes should have the same magnetic field strengths, the same field profiles, the same thermodynamical conditions and Doppler shifts.

Without doubt, this presents an important mystery of the solar magnetism. In fact, during the acquisition of the magnetogram (about several minutes to several tens of minutes) we observe many fluxtubes, which have a relatively short life-time (about several minutes, as it follows from filigree observations) and somewhere occur, somewhere decay. So, we can expect, that their magnetic field strengths and other parameters *are not constant* during the observations. But, in this case, we should observe *no constant* line ratio – for example, from $\boldsymbol{B}_{\|}(5233)/\boldsymbol{B}_{\|}(5250) = 2$–$3$ for maximum field concentration to $\boldsymbol{B}_{\|}(5233)/\boldsymbol{B}_{\|}(5250) \approx 1$ for a time when the fluxtube is born or when it decays. Finally, we must obtain no narrow dependence on "$\boldsymbol{B}_{\|}(5233) - \boldsymbol{B}_{\|}(5250)$ diagram", but a *wide sector of measures.* Wonderfully, we do not observe this effect!

One of possible explanations is the following. Maybe, processes of the birth and decay are very short in time, and escape our attention on 'line ratio diagram'. On the other hand, new observations by Cerdena *et al.* (2003) indicate *some dispersion* of line ratio, namely $\boldsymbol{B}_{\rm eff}(630.15)/\boldsymbol{B}_{\rm eff}(630.25) = 1.25 \pm 0.14$, which could indicate the 'trace' of the rapid stages (begin and final) of the fluxtube evolution. Another possibility: perhaps, is that during the fluxtube evolution their main magnetic characteristics are constant, although their diameter changes essentially.

No constant line ratios was obtained earlier by Lozitsky & Tsap (1989). They published the observations for the quiet regions with *two line ratios*, namely $\boldsymbol{B}_{\|}(5184)/\boldsymbol{B}_{\|}(5253) = 1.50$ and 1.15. As it follows from model calculations, first case corresponds to fluxtube field, whereas second one – almost homogeneous field like 'canopy' (Giovanelly 1980) at Mg I 5184 formation level.

So, the problem of line strength ratio variability is very important, practically unexplored and needs an additional study in the future.

6. Conclusion

Although the kilogauss concept occurred firstly from the line-to-line strength ratio problem, there is a separate problem of the line ratio differences. The reality of the kG fields in solar small-scale fluxtubes follows not only from line ratio method, but also from other techniques: spectral-polarized observations (see e.g., Kouchmy & Stellmacher 1978; Lozitsky 1980, 1986; Lozitska & Lozitsky 1994; Lozitsky *et al.* 2000, etc.), Fourier transformation technique (Stenflo *et al.* 1984; Solanki & Stenflo 1984; Keller *et al.* 1990, etc.), magnetic field measurements using the infrared lines (Harvey & Hall 1975; Stenflo 1989; Muglach & Solanki 1992, etc.), and last observations with best parameters of the direct spatial resolution (Cerdena *et al.* 2003).

From all these observations, it follows that solar fluxtubes with kG fields *occur on the Sun anywhere* – from very quiet regions to active regions and flares, and likely, from center of solar disk to solar pole. As to last, let us remember that about 30 years ago Gopasyuk *et al.* (1973) measured $\boldsymbol{B}_{\|}(6103)/\boldsymbol{B}_{\|}(5250) = 1.45$ at disk center, and $\boldsymbol{B}_{\|}(6103)/\boldsymbol{B}_{\|}(5250) \approx 1.3$ at north pole. In the case of homogeneous field, we should obtain $\boldsymbol{B}_{\|}(6103)/\boldsymbol{B}_{\|}(5250) \approx 1$ in both cases. So, these very old, but very important observations indicate indirectly that fluxtube structure of the solar magnetic field presents on the Sun even outside the zone $|\Delta\phi| = 5$–40°, where the sunspots occur. It will be very interesting to compare the magnetic properties of fluxtubes in the named zone and outside the zone, but this task needs additional and careful studies in the future.

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