RELATIVE BRIGHTNESS VARIABILITY VS. AVERAGED DOPPLER SHIFT IN THE QUIET SUN

A. Brković[1], H. Peter[2], and S.K. Solanki[3]

[1]Kiepenheuer-Institut für Sonnenphysik, Schöneckstrasse 6, 79104 Freiburg, Germany
[1]Institute of Astronomy, ETH-Zentrum, CH-8092 Zürich, Switzerland
[2]Kiepenheuer-Institut für Sonnenphysik, Schöneckstrasse 6, 79104 Freiburg, Germany
[3]Max-Planck-Institut für Aeronomie, Max-Planck-Str. 2, 37191 Katlenburg-Lindau, Germany

ABSTRACT

We studied SUMER and CDS time series of spectra and images of quiet-Sun regions at disc centre. Ultraviolet emission lines sampling temperatures of the chromosphere, transition region and corona were recorded. We found a high correlation between average net Doppler shifts and relative brightness variabilities of the studied lines. We point to some basic ideas which could eventually model the variability-Doppler shift relationship.

Key words: Sun: chromosphere – Sun: corona – Sun: transition region – Sun: UV radiation.

1. INTRODUCTION

Porter et al. (1984) discovered transition region brightenings in an active region lasting typically less than 1 minute, while Rabin & Dowdy (1992) reported on transition region brightenings lasting longer than 5 minutes and found that most of the significant fluctuations last for $\leq$ 10 minutes. Recently, Brković et al. (2000) found that the relative intensity variations are strongest in the transition region lines and are dominantly due to the brightness changes on time scales less than 80 min and longer than 5 min. Studies of line intensities, shifts, widths and their relationships are largely represented in the literature, both on theoretical (e.g., Hansteen 1993 and observational (e.g., Peter & Judge 1999, Teriaca et al. 1999) basis. We try to establish the connection between *relative* changes in line intensities and net Doppler shifts.

2. OBSERVATIONS

The observations of quiet regions at Sun centre have been made using the Solar Ultraviolet Measurements of Emitted Radiation (SUMER) spectrometer (Wilhelm et al. 1995) and the Normal Incidence Spectrometer (NIS) of the Coronal Diagnostic Spectrometer (CDS, Harrison et al. 1995) onboard the SOHO spacecraft. A list of the lines analysed and temperatures of line formation are given in Table 1. The Mg IX 368.1 Å line was observed only with CDS, He I 584.3 Å and O V 629.7 Å were observed with both CDS and SUMER, and all other lines were observed only with SUMER. These lines cover temperatures from the chromosphere, transition region and corona.

SUMER observed with detector B on 14, 16 and 25 February 1997 using the $1'' \times 300''$ slit and on 22, 23 and 25 April 1997 using the $1'' \times 120''$ slit, with a pixel size of $1'' \times 1''$ in both cases. The SUMER slit was kept at a fixed location on the solar surface by compensating for solar rotation. CDS/NIS was employed in its movie mode, i.e., with a $90'' \times 240''$ slit, with a pixel size of $1.68'' \times 1.68''$. After correction for solar rotation each pixel follows the same point on the solar surface during the whole time series. For more informations about observations see also Brković et al. (2000,2002).

3. RESULTS

The time variability, δI, is described by the RMS variation of the intensity during the time series. The (average) intensity, I, is the average over the whole duration of the observations. The relative variability $\delta I/I$ is defined as the ratio of the RMS to the intensity. These three parameters were determined for each spatial pixel for the spectral lines of interest.

In Figs. 1a(b) we plot the relative variability and mean Doppler shift of each spectral line as a function of its temperature of formation. The bars are standard deviations.

The temperature dependence of the mean (spatially and temporally averaged) Doppler shift (v_{DS}) and the relative variability are similar (cf. Fig. 6 of Peter & Judge 1999 or Fig. 10 of Teriaca et al. 1999). The agreement between the results of these independent investigations is remarkable and encouraging. We face the problem that these authors analysed some spectral lines not present in our sample and vice versa. There are twelve common ions, designated by asterisks in the Table 1, for which are measured both the relative variability and the Doppler shift. Since the N I 1319.0 Å is a chromospheric line formed at very similar temperatures as O I and Si II we obtained the mean Doppler shift for this line averaging the shifts of the former two ions. We also suppose that the Doppler shift of the Mg IX 368.1 Å line does not differ too much from the one of the Mg X 625.0 Å line.

Figure 1c shows the average relative variability as a function of Doppler shift. The solid line is a linear fit through

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Table 1. SUMER and CDS lines. Asterisks denote ions observed by Peter & Judge (1999) or Teriaca et al. (1999). Line formation temperatures T_e according to Landini & Monsignori Fossi (1990).

Line (Å)	log (T_e/K)	Line (Å)	log (T_e/K)	Line (Å)	log (T_e/K)	Line (Å)	log (T_e/K)
Mg IX 368.1	6.00	S VI* 933.4	5.28	C I* 1267.7	4.18	N I 1319.0	4.21
He I* 584.3	4.50	O VI* 1031.9	5.47	O I* 1302.2	4.18	C II* 1334.5	4.60
O V* 629.7	5.39	O I* 1152.1	4.18	O I* 1304.9	4.18		
Ne VIII* 770.4	5.81	C III* 1175.7	4.80	Si II* 1309.3	4.10		

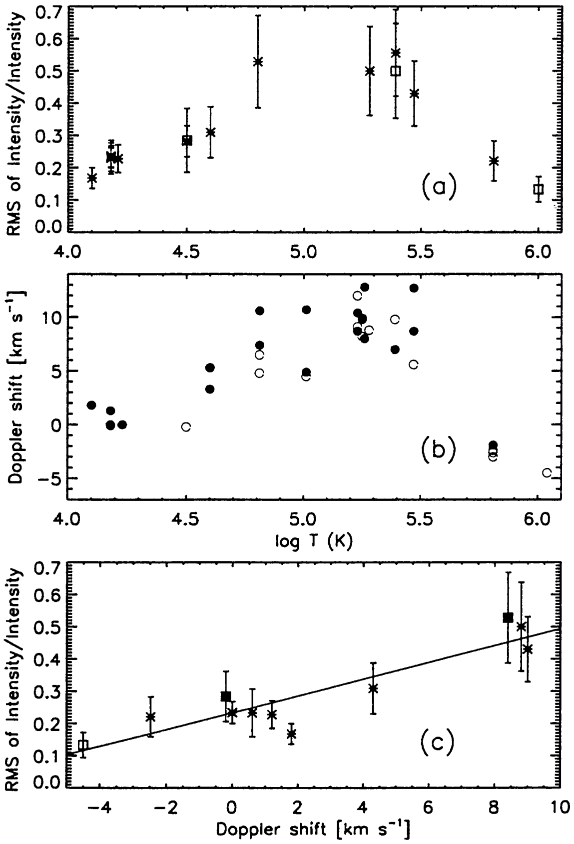

Figure 1. Relative variability vs. formation temperature (a), mean Doppler shift vs. formation temperature (b) and relative variability vs. mean Doppler shift (c). Squares refer to the CDS data and asterisks to SUMER in (a) and (c), while open circles refer to Peter & Judge (1999), filled circles to the Teriaca et al. (1999) measurements in (b). Errors in Doppler shifts are typically $1-2$ *km* s^{-1} *(see original papers).*

the points,

$$\delta I/I = 0.233(\pm 0.026) + 0.020(\pm 0.004) v_{DS}. \quad (1)$$

The correlation coefficient between the relative variability and Doppler shift is 0.91. It suggests a physical connection between these two quantities. One proposal for this connection is presented in the next section.

4. MODEL

The close relation between intensity fluctuations and Doppler shifts suggests that some periodic process might be involved. Following a numerical model for the transition region line shifts by Hansteen (1993) we propose that the basic process is a compressible wave, e.g. a sound wave, that is neither spatially nor temporarily resolved by the observations. Let us assume that the nanoflares that are producing the waves are occurring mainly at around $\log T \approx 5.5$ in order to produce the observed redshifts in the cooler lines and the blueshifts in the hotter lines, as it was proposed by Peter & Judge (1999). Then just around these temperatures one would not expect the phase lag being clearly 0 or π, as it is the case further away from the nanoflare regions. Therefore at those temperatures the Doppler shift vanishes, but in the lower and middle transition region and lower corona the relation $v_{\rm D} \propto \widehat{I}/I_0$ still holds, as it can be seen from Fig. 1c.

5. CONCLUSIONS

We have investigated the brightness variations in the quiet Sun using time series obtained by SUMER and CDS in chromospheric, transition region and coronal lines. We found the high correlation between averaged Doppler shifts and relative variabilities of the studied lines. A further discussion can be found in Brković et al. (2002).

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