Doppler Shifts in the Transition Region of Active Regions

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Abstract

Emission lines from the transition region (TR) show, on average, persistent redshifts in the quiet Sun. In active regions the situation has been less clear, mainly because of limited data with sufficiently accurate wavelength calibration; SUMER did observe only few active regions, EIS is not really covering lines from the transition region at 100.000 K.

The aim of this study is to use IRIS data to investigate the average of transition region Doppler shifts in active regions and their spatial distribution, and by this close an observational gap.

Our results indicate that the net Doppler shifts in the transition region of active regions is smaller than thought before, close to values found for the quiet Sun, and more similar to what models of emerging active regions predict.

INTRODUCTION

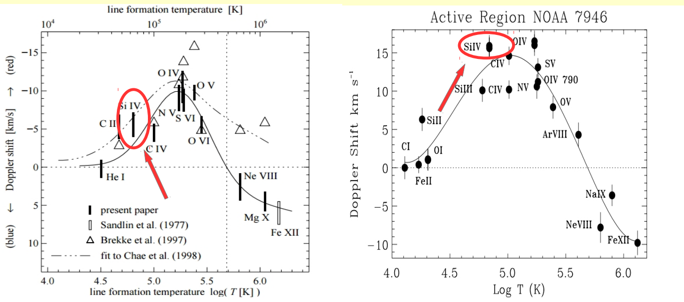


Figure 1. Dependence of the Doppler shift on the formation temperature of TR lines in full quiet sun disk (left, Peter & Judge 1999, ApJ, **522**:1148-1166) and in one active region (right, Teriaca, Banejee & Doyle, 1999, A&A, **349**:636-648).

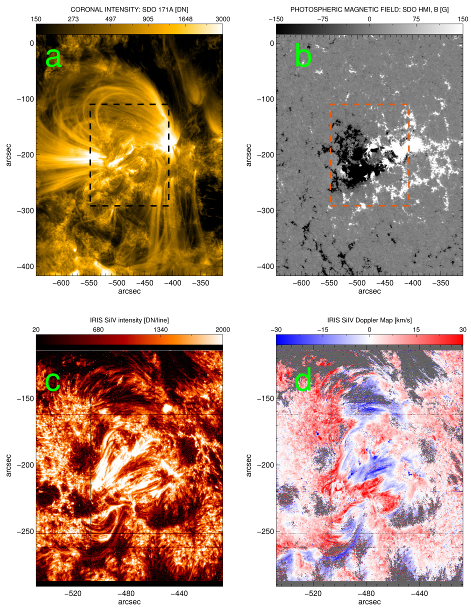
Studies with SUMER have shown a clear pattern in the Doppler shift of TR lines which depends on the temperature at which the lines are formed. The lines show almost no redshift in the lower (and cold) part of the TR, then the redshift reaches a maximum at temperatures of the order of 10^5 K.

Lines that form at a temperature hotter than $10^{5.7}$ K show a blueshift instead.

SUMER observations suggest that the pattern of Doppler shift with line formation temperature is similar for quiet Sun and active regions, just with a different amplitude (see Figure 1). For Si IV the values are 5 km/s and 15 km/s. However SUMER observations of active regions are limited in number, because of count-rate limitations. Therefore the observational basis for reliable active region Doppler shift is limited.

The active region observations by SUMER relies on a single slit position on a single active region and thus may or may not be representative of active regions on the Sun in general. We use IRIS observations of several active regions in Si IV to close this observational gap.

Sample active region: AR 12335



Analysis

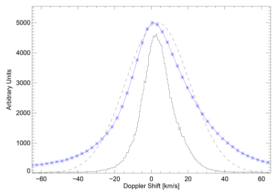


Figure 2. The figure shows the Si IV line integrated over the whole region (blue starred line), a gaussian fit to the line (black dashed line), and the distribution of the Doppler shift computed in each resolved point of the region.

Our analysis has been done using large dense rasters of 8 active regions.

To characterize the average Doppler shift of the region we compute the average spectrum of all data points in the covered field-of-view. In general, this is slightly asimmetric (blue line) which is why we derive the position of the best-fit Gaussian, take the 1st moment of the profile, and estimate the position of the peak (see table below).

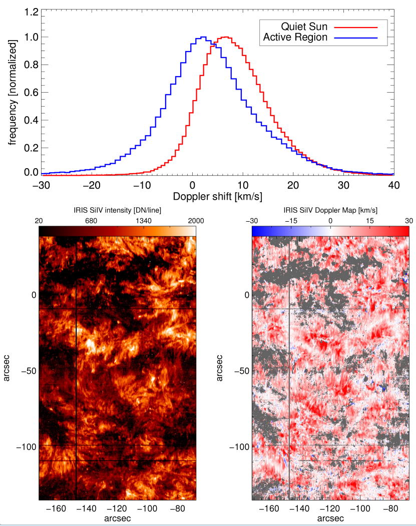
We compare this to the spatial distribution of the Doppler shifts, the histogram of which is shown as a black line. The mean and the median position are given in the table below.

	Dataset	AVERAGE SPECTRUM			DISTRIBUTION	
		Gauss Fit (km/s)	1st Moment of the line profile (km/s)	Peak position (with spline) (km/s)	Mean (km/s)	Median (km/s)
1.	20140618 181004 3824007696	3.5	4.8	2.3	0.6	2.4
2.	20150420 075944 3820256896	5.9	7.9	4.3	7.1	7.3
3.	20150429 012946 3820009196	3.9	3.4	3.3	3.4	3.6
4.	20150429 063309 3820009196	6.2	8.8	4.3	5.7	6.1
5.	20150501 211654 3820009196	6.8	8.3	5.3	4.7	5.2
6.	20150504 122043 3820009196	2.8	5.2	1.1	3.3	3.1
7.	20150504 133405 3820009196	5.8	8.0	4.3	5.2	5.9
8.	20150505 054924 3820259496	4.3	4.4	3.3	4.7	4.7

While the average line profile is asymmetric, the three proxies for the Doppler shift are mostly within the error of the wavelength calibration (±1 km/s).

Mostly, also the mean and the median of the Doppler shifts in the map are similar to the shift of the average profile. The typical Doppler shift in the active regions is of the order of 5 km/s, i.e. similar to the quiet Sun.

Comparison with the Quiet Sun velocity distribution and spatial distribution



While the average Doppler shift of active regions and quiet Sun are comparable, there are significant differences:

- the distribution (histogram) of the Doppler shift is clearly more blue in the active region;
- in the quiet Sun the whole area is redshifted (left map), while in active regions a significant fraction of the area is blueshifted (above map);
- in active regions we see clear indications of siphon flows along loops, which are not present in the quiet Sun.

Figure 3. The top panel shows the comparison between the velocity distribution of the QS (red line) and the velocity distribution of the AR (blue line). The bottom panels show the IRIS SiIV intensity map (left) and the Doppler map (right).

CONCLUSIONS:

- **The average net Doppler shift in the transition region of active regions is smaller than thought before: only about 5 km/s instead of 15 km/s;**
- **The observed Doppler shift is similar to what models of emerging active regions predict (Peter, Gudiksen, Nordlund, 2006);**
- **The average active region shift is close to the shift in quiet Sun**
- **The spatial distribution of Doppler shift is significantly different in active region compared to the quiet Sun.**

References:

Peter, Gudiksen & Nordlund, 2006, ApJ 638,1086
Peter & Judge, 1999, ApJ, 522:1148-1166
Teriaca, Banejee & Doyle, 1999, A&A, 349:636-648
Chen, Peter, Bingert & Cheung, 2014, A&A, 564, A12

Poster

3. Magnetic coupling and mass flux through the atmosphere

Doppler shifts in the transition region of active regions.

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Since the first observations in 1976, emission lines from the transition region (TR) have shown, on average, persistent redshifts in the quiet Sun (QS). There are many observations of the QS at TR temperatures (with SUMER) and there are numerous studies of active regions (ARs) at coronal temperatures (with EIS). However, there is a lack of investigations of (average) AR Doppler shifts at TR temperatures. The aim of this study is to use IRIS data to investigate TR Doppler shifts in ARs and their spatial distribution. By this we close an observational gap.
We investigate large dense rasters by IRIS of 8 ARs. To characterise the average Doppler shift of the respective region, we compute the average spectrum of all data points in the covered field-of-view. In general, this is asymmetric with an extended wing towards the red. Actually, the spatial distribution of the Doppler shifts (i.e. the histogram of the shifts of individual spectra) shows a similar asymmetric profile.
Our results indicate that the net Doppler shifts in the TR of ARs is smaller than thought before, and is close to values found for the QS, i.e. about 6 km/s to 8 km/s. However, the spatial distribution of the Doppler shifts in an AR is significantly different to the QS. These observational results provide another aspect for a test of 3D MHD models and would be consistent with ARs models based on heating of the corona by field line braiding.