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Spectral Analysis of the Chromospheric Network via Si IV emission lines

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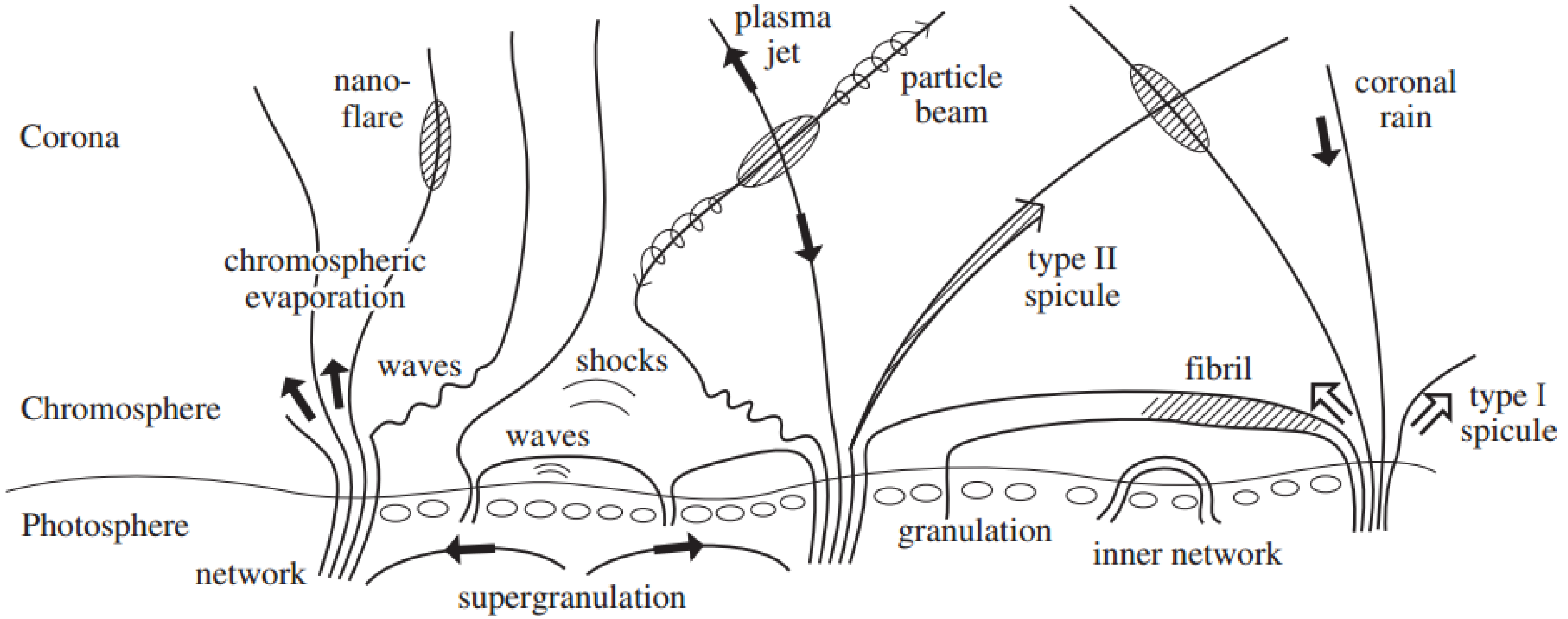
Outline

- Introduction
- Chromospheric network and internetwork
- Data properties
- Data analysis
- Results

▪ Introduction

Chromosphere and Transition region

The chromosphere and transition region are the two main layers of the solar atmosphere that are the least known due to their complicated structures.



▪ Introduction

Chromosphere and Transition region

Studying the emission line profiles in solar UV spectra which originate from chromosphere and TR provide:

- ✓ **The energy and mass flux transport mechanisms from the photosphere to corona**
- ✓ **The responsible heating mechanism in solar chromosphere**

▪ Introduction

Alister & Wolf 1972

The line profiles with wider spectral width than thermal width at TR temperature.

1973 Boland et al.

Propagating mechanical sound waves or presence of MHD waves.

Doschek et al. 1976

The line widths are slightly larger in the coronal hole in comparison with quiet Sun close to disk center.

1977 Kjeldseth-Moe & Nicolas

For the first time they fitted the line profile with two Gaussian curves: one for the main core and another for the enhanced emission.

Athay & White 1978

There is another mechanism to heat upper chromosphere expect propagating mechanical sound waves.

1993 Dere & Mason

The non-thermal velocities of emission lines in the temperature range of 10^4 to 10×10^6 K over the quiet Sun and active region.

Peter 2000

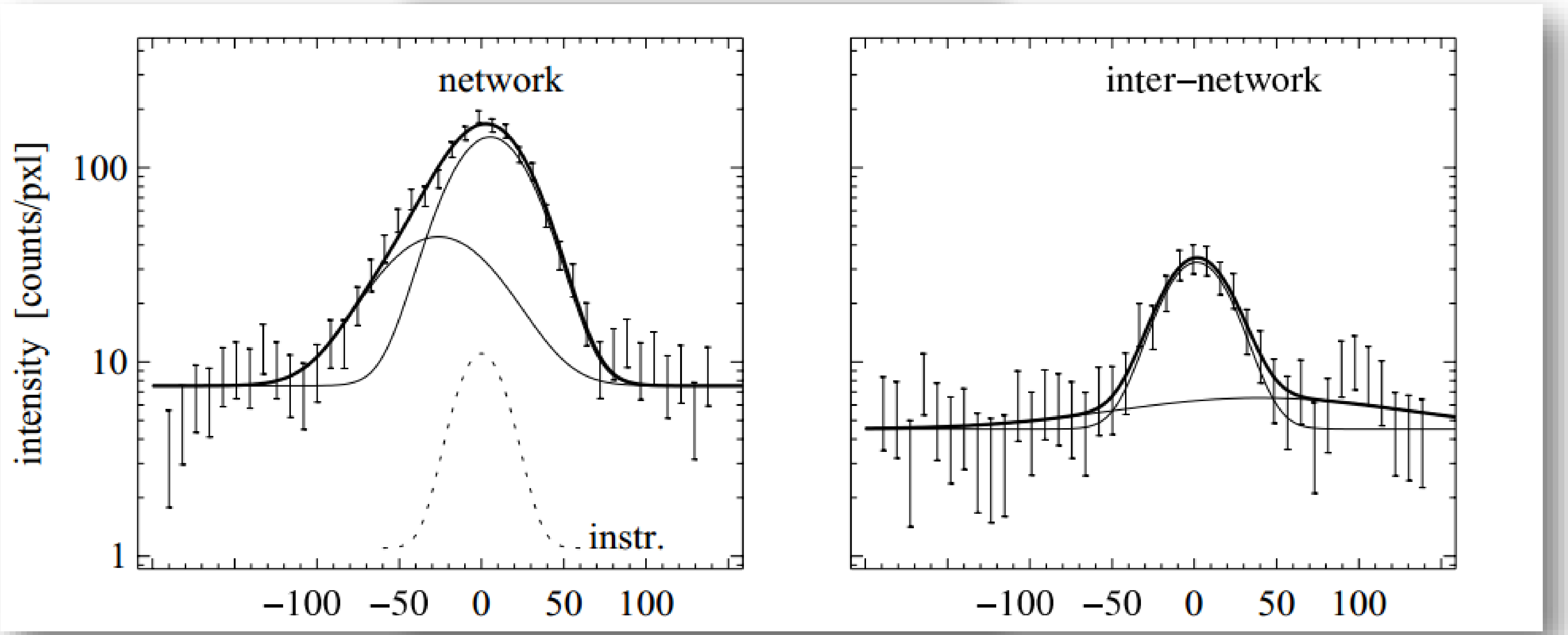
- The narrow component associated with the small scale loops.
- The broad component associated with the footpoints of the large scale loops.

2003 Sim & Jordan

The narrow component relate with the coronal funnels (in contrary to the findings of peter)

Chromospheric network and internetwork

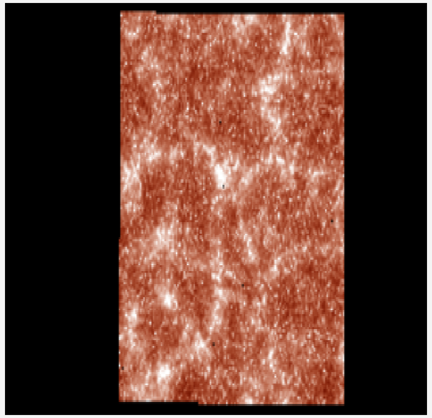
The chromospheric network areas has stronger magnetic field than internetwork regions. The EUV spectrum of the network regions is observed to have broader line consist of two Gaussian component: A main component (core) and a blended one (Peter, H., 2000).

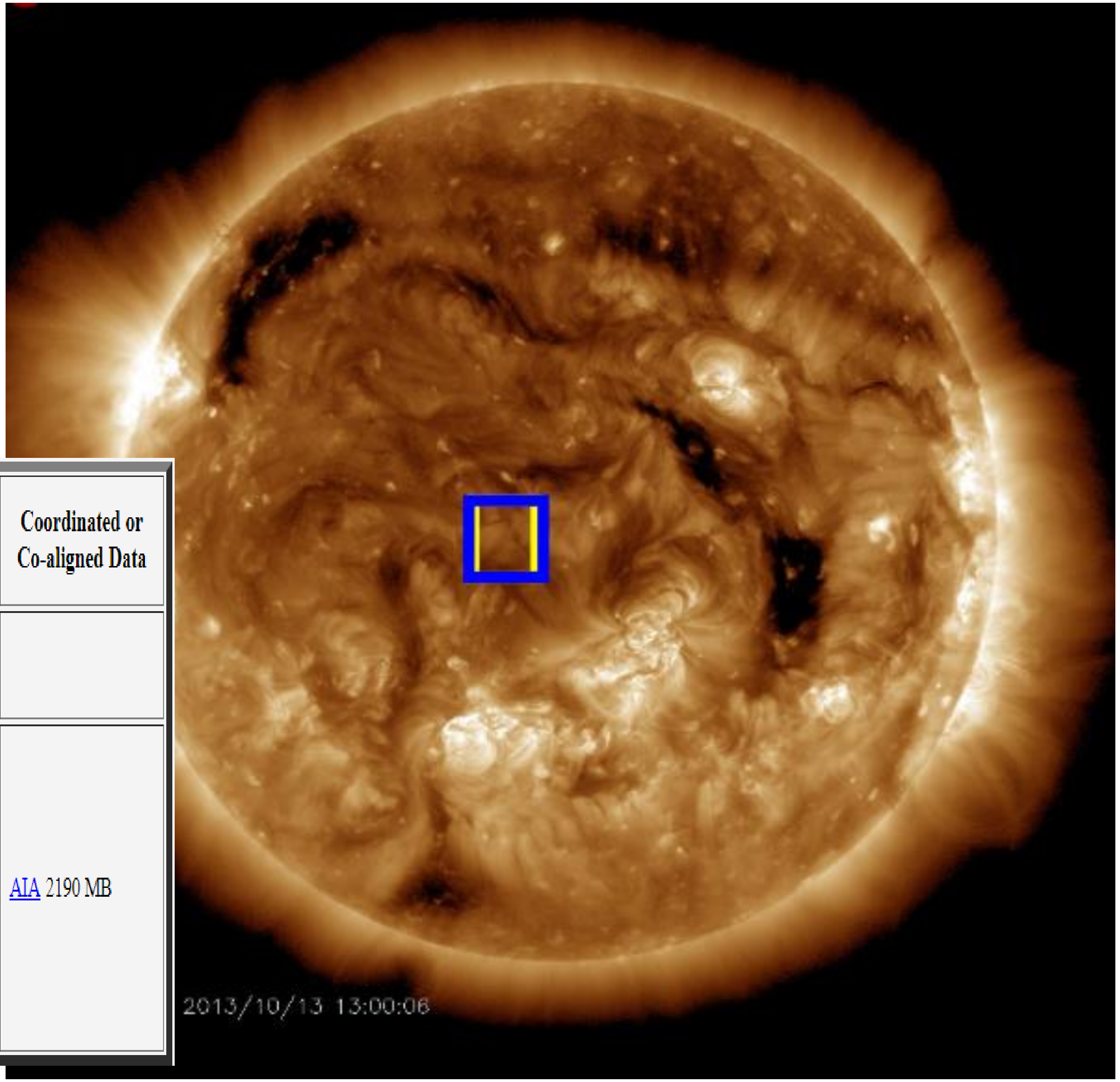


Peter, H., 2000, A&A, 360, 761-776

Data properties

Spatial resolution **: (0.35 , 0.16) arcsec** in the solar X & solar Y directions
Spectral resolution **: 12.5 mÅ/pix**
Step cadence **: 32 s**
Data's level **: level 2**

Overview	Where	Raster	SJI wavel: cadence, # images	Data Links	Coordinated or Co-aligned Data
2013-10-13 23:27:28-02:59:15 +1d 	Quiet Sun Hinode Observation OBS 3820013446: Very large dense raster			Annotate	
	x,y: -120",-41" Max FOV: 307"x174" Target: QS Nearby Events	FOV: 141"x174" Steps: 400x0.35" Step Cad: 31.8s Raster Cad: 12,706s, 1 ras Linelist: v38_01	FOV: 167"x174" 1400: 62s, 153 imgs 2796: 62s, 153 imgs	Raster 904 MB 1400 244 MB 2796 244 MB AllMovies 1372 MB	AIA 2190 MB



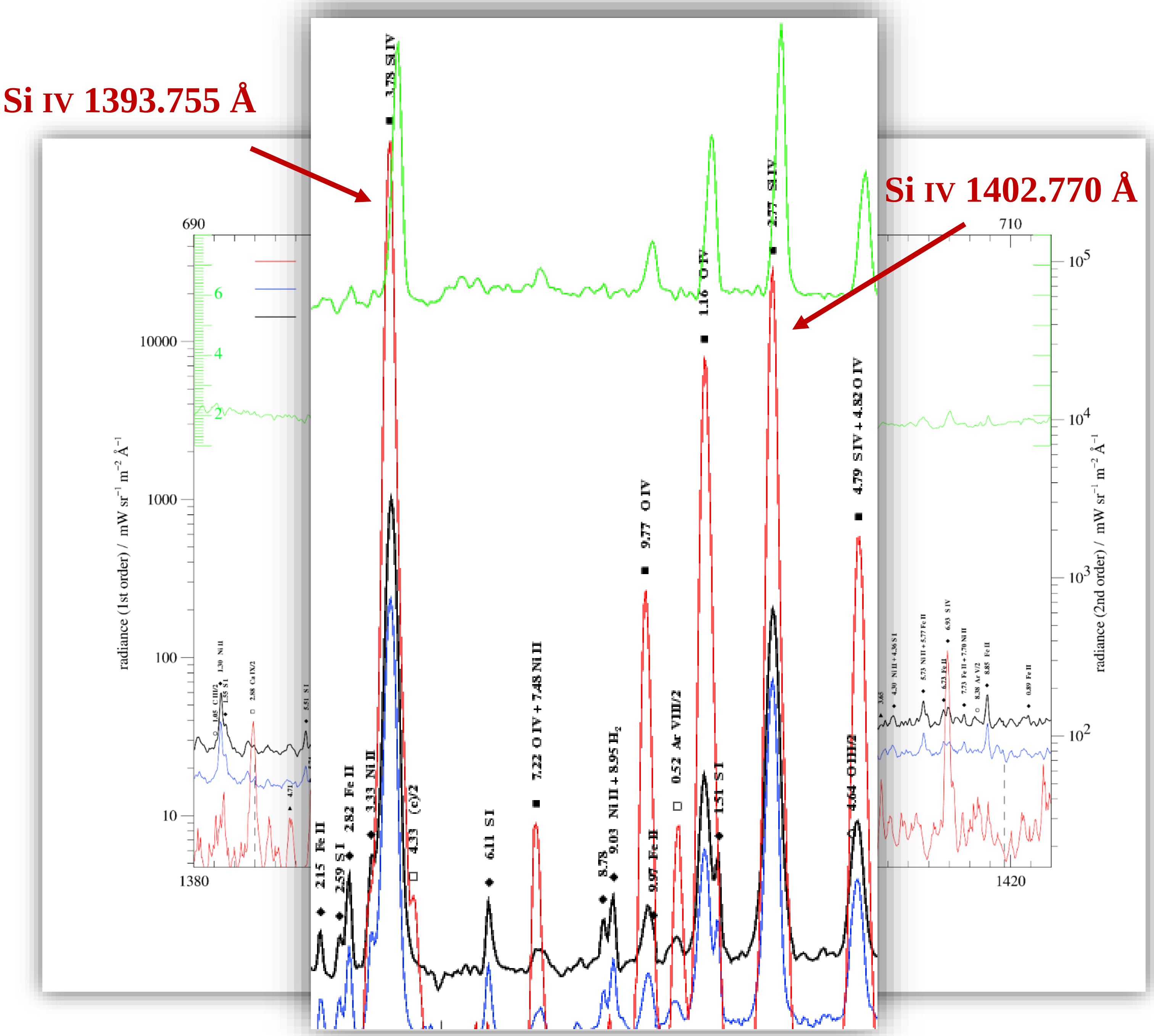
http://iris.lmsal.com/search/

Data properties

The part of **VUV** solar spectrum:

Si IV 1393.755 Å

Si IV 1403.770 Å



- Data analysis
  - Fitting a one or two Gaussian curves:

$$y = A\exp\frac{-(\lambda - \lambda_0)^2}{\sigma^2} + Bx + C$$

$$y = A\,exp\frac{-(\lambda - \lambda_0)^2}{\sigma^2} + A'\;exp\frac{-(\lambda - \lambda'_0)^2}{\sigma^2} + Bx + C$$

  - Doppler shift:

$$v_{LOS} = c\,\frac{\lambda - \lambda_0}{\lambda_0} \qquad \text{(km/s)}$$

  - Line width:

$$\Delta\lambda_{th} = \left(\frac{2\,k_B\,T}{m}\right)^2 \qquad \text{(km/s)}$$

$$\Delta\lambda_{inst.} = \Delta\lambda_{inst.}(\text{Å})\,\frac{c}{\lambda_0} \qquad \text{(km/s)}$$

$$\Delta\lambda_{nth} = \left(\Delta\lambda_{obs}{}^2 - \Delta\lambda^2{}_{th} - \Delta\lambda^2{}_{inst.}\right)^{1/2} \qquad \text{(km/s)}$$

Data analysis

- Energy flux of sound wave :

$$\mathbf{F_{sound} = \frac{3}{2}\,\rho\,\xi^2\,v_{sound}}$$

$$(\mathbf{erg\ arcsec^{-2}\ s^{-1}})$$

- Energy flux of Alfven wave :

$$\mathbf{F_{Alfven} = \frac{3}{2}\,B\left(\sqrt{\frac{\rho}{4\pi}}\right)\xi^2}$$

$$(\mathbf{erg\ arcsec^{-2}\ s^{-1}})$$

- Energy flux of turbulence:

$$\mathbf{F_{turb.} = 1.84\,\rho\,\xi^3}$$

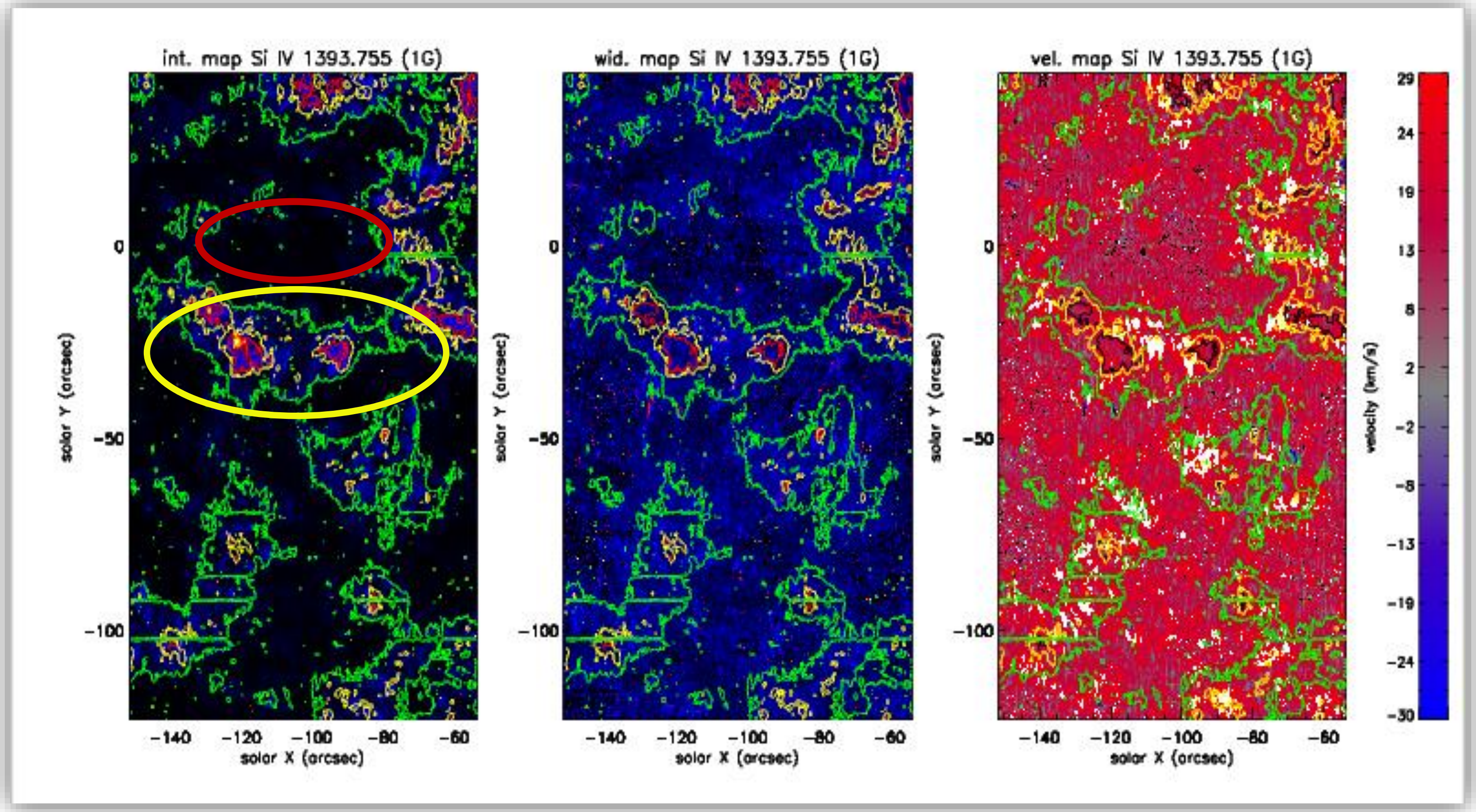
$$(\mathbf{erg\ arcsec^{-2}\ s^{-1}})$$

H., Peter, 2000 & Wood B.E., Linsky J.L., Ayres T.R., 1997

Data analysis

The left, middle and right panels of this figure show the peak intensity, width and Doppler shift maps of the studied region for **Si IV 1393.755 Å** chromospheric emission line.

Peak intensity **Line width** **Doppler shift**



Data analysis

Network area

- **Region 1:** the intensities larger than **120 DN**.
- **Region 2:** the intensities smaller than **120 DN** and larger than **85 DN**.
- **Region 3:** the intensities smaller than **85 DN** and larger than **45 DN**.

Internetwork : the intensities smaller than **45 DN**.

▪ Results

Calculating Doppler shift & Line width (Si IV 1394 Å)

- ✓ The core components show average redshifts and the blended components show average blueshifts.
- ✓ The network region show a larger width respect to internetwork areas.

	Doppler shift (km/s)			Line width (km/s)		
	2G_2 fit (Core)	2G_1 fit (Blend)	1G	2G_2 fit (Core)	2G_1 fit (Blend)	1G
Region 1	23.9 ± 1.8	-6.9 ± 1.1	11.1 ± 0.3	16.1 ± 1.2	12.9 ± 2.3	16.8 ± 0.2
Region 2	24.2 ± 0.4	-6.8 ± 0.9	11.0 ± 0.4	15.6 ± 1.2	12.9 ± 0.7	17.2 ± 0.4
Region 3	23.1 ± 1.7	-6.1 ± 1.3	10.8 ±0.7	14.8± 1.1	12.3 ± 0.9	16.5 ± 0.7
Network	23.3 ± 0.6	-6.2 ± 1.3	10.8 ± 0.6	14.9 ± 1.1	12.4 ± 1.9	16.6 ± 0.6
Internetwork	23.1 ± 0.4	-5.8 ± 1.3	10.2 ± 0.8	12.2 ± 1.3	10.2 ± 1.7	14.0± 1.1
All areas	22.8± 1.7	-5.9 ± 1.8	10.4 ± 1.4	13.2 ± 2.1	11.0 ± 2.4	14.9 ± 1.3

▪ Results

Calculating Doppler shift & Line width (Si IV 1403 Å)

- ✓ The core components show average redshifts and the blended components show average blueshifts.
- ✓ The network region show a larger width respect to internetwork areas.

	Doppler shift (km/s)			Line width (km/s)		
	2G_2 fit (Core)	2G_1 fit (Blend)	1G	2G_2 fit (Core)	2G_1 fit (Blend)	1G
Region 1	24.8 ± 1.2	-6.4 ± 2.3	12.6 ±1.4	16.8 ± 1.3	9.9 ± 0.3	16.6 ± 1.2
Region 2	24.6 ± 1.5	-5.7 ± 1.6	14.0 ± 1.8	15.9 ± 0.9	10.8 ± 0.3	17.1 ± 1.5
Region 3	26.0 ± 1.6	-7.0 ± 1.7	9.7± 0.8	15.0 ± 0.9	10.8 ± 1.0	16.6 ± 1.2
Network	25.8 ± 1.6	-6.8 ± 1.3	10.4 ± 0.9	15.2 ± 0.8	10.8 ± 1.7	16.7 ± 1.1
Internetwork	25.7 ± 2.1	-7.0 ± 1.0	9.1 ± 0.6	11.5 ± 1.4	9.9 ± 0.1	14.2± 0.8
All areas	26.3 ± 2.4	-7.4 ± 1.4	7.9 ± 1.9	12.8 ± 2.1	10.2 ± 3.3	15.1 ± 1.9

Results

Calculating correlation coefficients (Si IV 1394 Å)

	Corr. Coeff (Dop.shift & int.)			Corr. Coeff (Line width & int.)		
	2G_2 fit (Core)	2G_1 fit (Blend)	1G	2G_2 fit (Core)	2G_1 fit (Blend)	1G
Region 1	-0.19	0.04	0.02	0.38	0.09	0.44
Region 2	-0.11	-0.05	-0.05	0.32	0.30	0.54
Region 3	-0.12	-0.02	-0.09	0.28	0.29	0.46
Network	-0.12	-0.01	-0.08	0.28	0.23	0.40
Internetwork	-0.13	0.08	0.11	0.15	0.10	0.12
All areas	-0.08	0.04	0.07	0.22	0.24	0.33

▪ Results

Calculating correlation coefficients (Si IV 1403 Å)

	Corr. Coeff (Dop.shift & int.)			Corr. Coeff (Line width & int.)		
	2G_2 fit (Core)	2G_1 fit (Blend)	1G	2G_2 fit (Core)	2G_1 fit (Blend)	1G
Region 1	-0.04	0.27	0.09	0.25	0.28	0.35
Region 2	-0.08	0.10	-0.03	0.31	0.41	0.44
Region 3	-0.09	0.11	-0.07	0.33	0.31	0.39
Network	-0.10	0.11	-0.06	0.27	0.30	0.32
internetwork	0.004	0.04	0.09	0.17	0.18	0.13
All areas	-0.01	0.07	0.07	0.29	0.28	0.27

Results

Calculating energy flux (Si IV 1394 Å)

	ξ (km/s)	Energy Flux (erg cm^{-2} s^{-1})		
		F_{Alfven}	F_{sound}	$F_{turb.}$
Region 1	14.03	5.68×10^4	5.09	2.37
Region 2	14.50	6.07×10^4	5.44	2.61
Region 3	13.74	5.45×10^4	4.88	2.22
Network	13.84	5.53×10^4	4.95	2.27
Internetwork	10.56	3.22×10^3	2.88	1.00
All areas	11.13	3.58×10^4	3.20	1.18

Results

Calculating energy flux (Si IV 1403 Å)

	ξ (km/s)	Energy Flux (erg cm^{-2} s^{-1})		
		F_{Alfven}	F_{sound}	$F_{turb.}$
Region 1	13.84	5.53×10^4	4.95	2.27
Region 2	14.45	6.03×10^4	5.40	2.59
Region 3	13.87	5.56×10^4	4.97	2.29
Network	13.93	5.60×10^4	5.02	2.32
Internetwork	10.90	3.43×10^3	3.07	1.11
All areas	12.01	4.17×10^4	3.73	1.48

Conclusions

- ✓ The core components show redshift where as the blended components show blueshift.

- ✓ There is no correlation between the intensities and the Doppler shifts however there is some correlation between the intensities and non-thermal velocities:

    - This might be due to the presence non-thermal horizontal (or inclined) flows in the network regions.
    - It is suggested that the horizontal (or inclined) flows can be created by the loops with different scales in the network regions.

- ✓ The results suggest that the dominant thermal mechanism in the chromospheric network might be via propagation of Alfven waves.

Thank you for your attention