Synthesized spectra of optically thin emission lines

K.Olluri[1], B. Gudiksen[1], V.Hansteen[1] & B. De Pontieu[2,1]
[1]Institute of Theoretical Astrophysics, University of Oslo, Norway
[2]Lockheed Martin Solar & Astrophysics Lab, Palo Alto, USA

ABSTRACT

3D numerical models try to recreate and mimic the solar atmosphere as seen from the observer in the best way, making it possible to do an in depth study of the physical quantities such as the temperatures, densities, magnetic fields etc. causing the phenomenons we observe on the sun. It has therefore become more and more common to use simulations in parallel with observations when analyzing spectra of the solar atmosphere. But the simulations have to be able to produce synthesized spectra that resembles previously reported results from observations. We will therefore here do a spectroscopic study of synthetic spectra created using the Bifrost code, and investigate how well the results hold when compared to reported results from observations. We present a study of the synthetic intensity, non-thermal linewidths, Doppler shifts, and correlations between any two of these three components of the spectra assuming statistical equilibrium.

METHOD

We use CHIANTI contribution functions for the emissivity:

$$\epsilon_\nu = G(T, n_e) n_e n_H$$

The line profile I_ν at each grid becomes; with v_ν and w_{th} the line of sight velocity and thermal width, respectively.

$$I_\nu = \epsilon_\nu \exp\left[-\frac{(v - v_v)^2}{w_{th}^2} \right].$$

Resulting in the total spectrum of the line, integrated overt the line of sight z:

$$I_v^{\rm synth} = \int_0^z I_v {\rm d}z$$

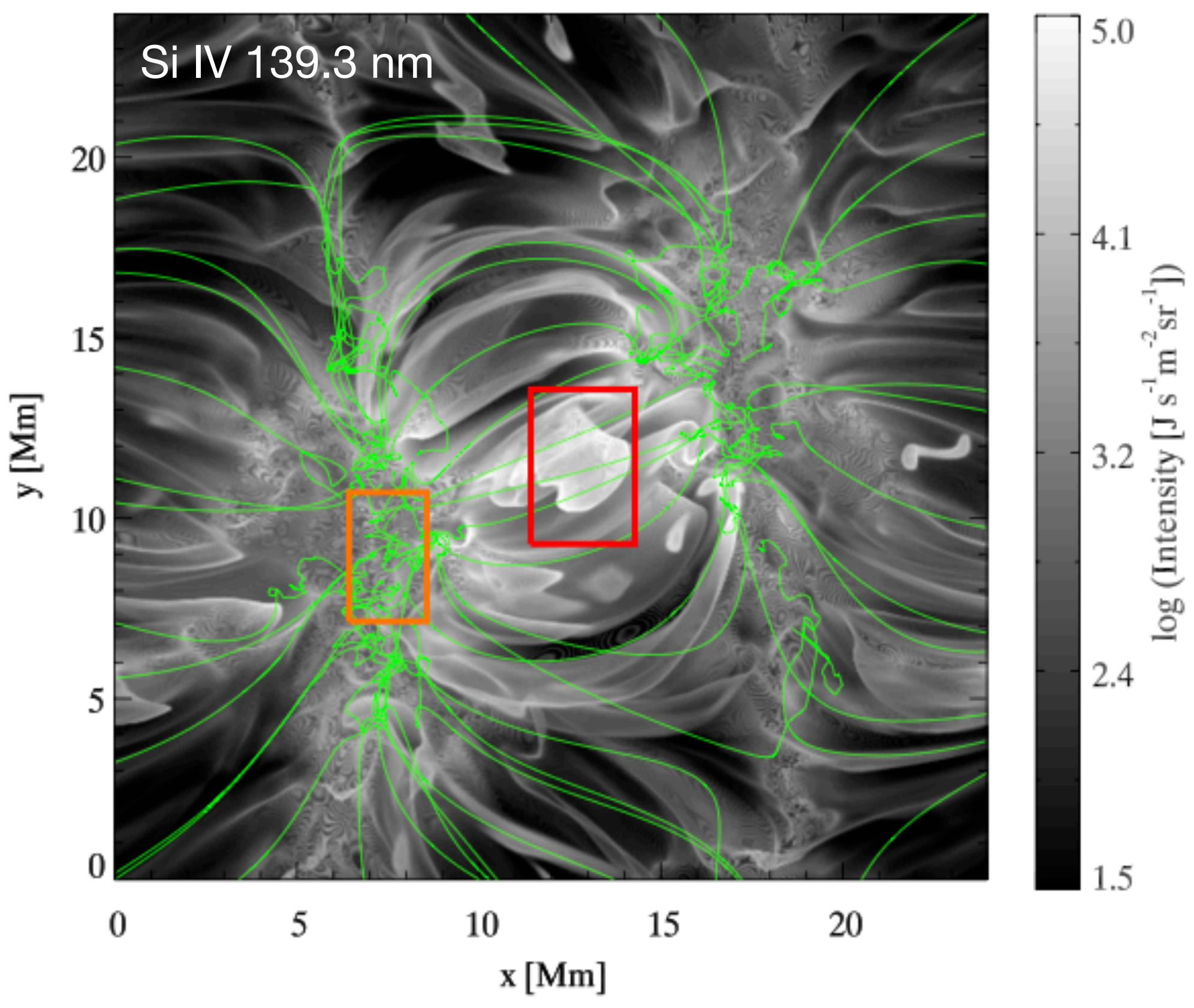
The data is synthesized by calculating the profile moments with respect to velocity, which give the line intensity, shift and width:

$$I^{\rm synth} = \int I_v^{\rm synth} {\rm d}v,$$

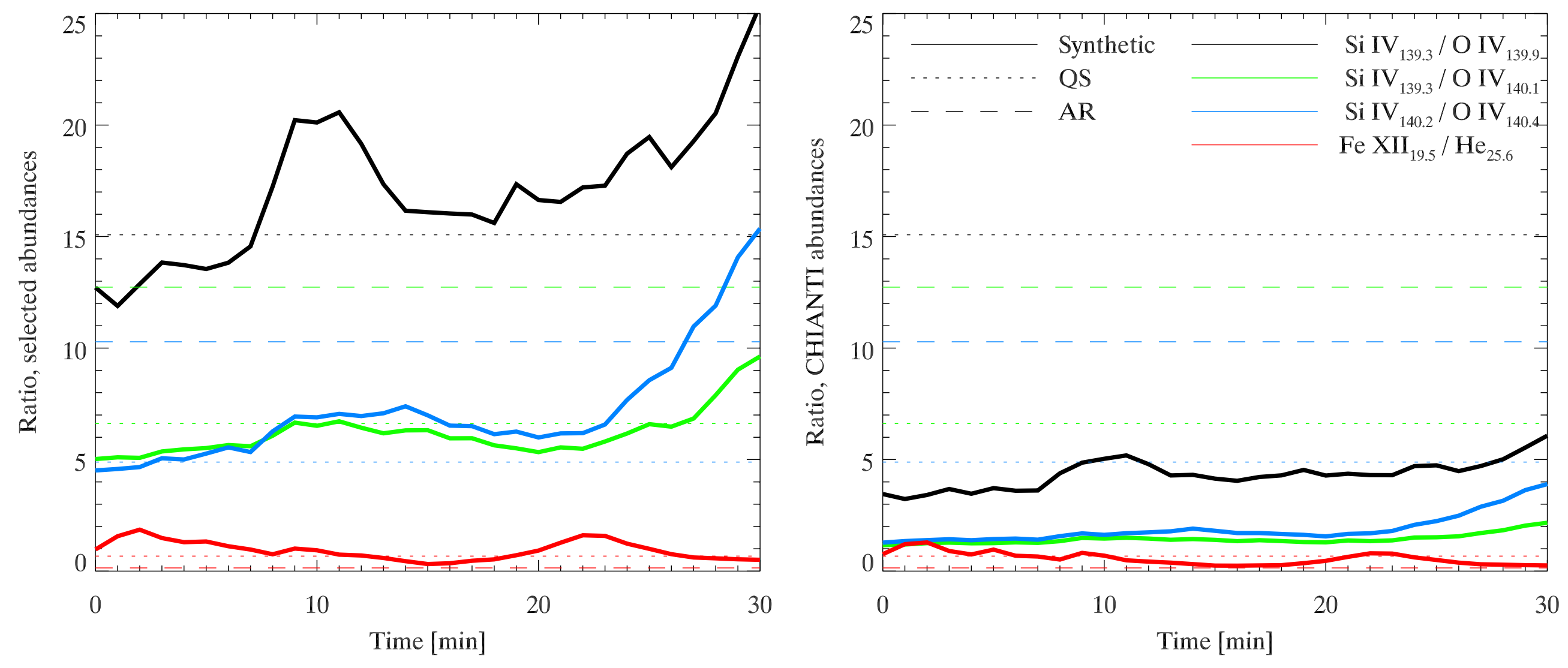
$$v^{\rm synth} = \frac{1}{I^{\rm synth}} \int v I_v^{\rm synth} {\rm d}v,$$

$$w^{\rm synth} = \sqrt{2} \cdot \left[\frac{1}{I^{\rm synth}} \int v^2 I_v^{\rm synth} {\rm d}v - (v^{\rm synth})^2 \right]^{1/2}$$

The data is rebinned to $1'' \times 1''$ cells before the analysis in order to simulate the spatial resolution of previous space missions.



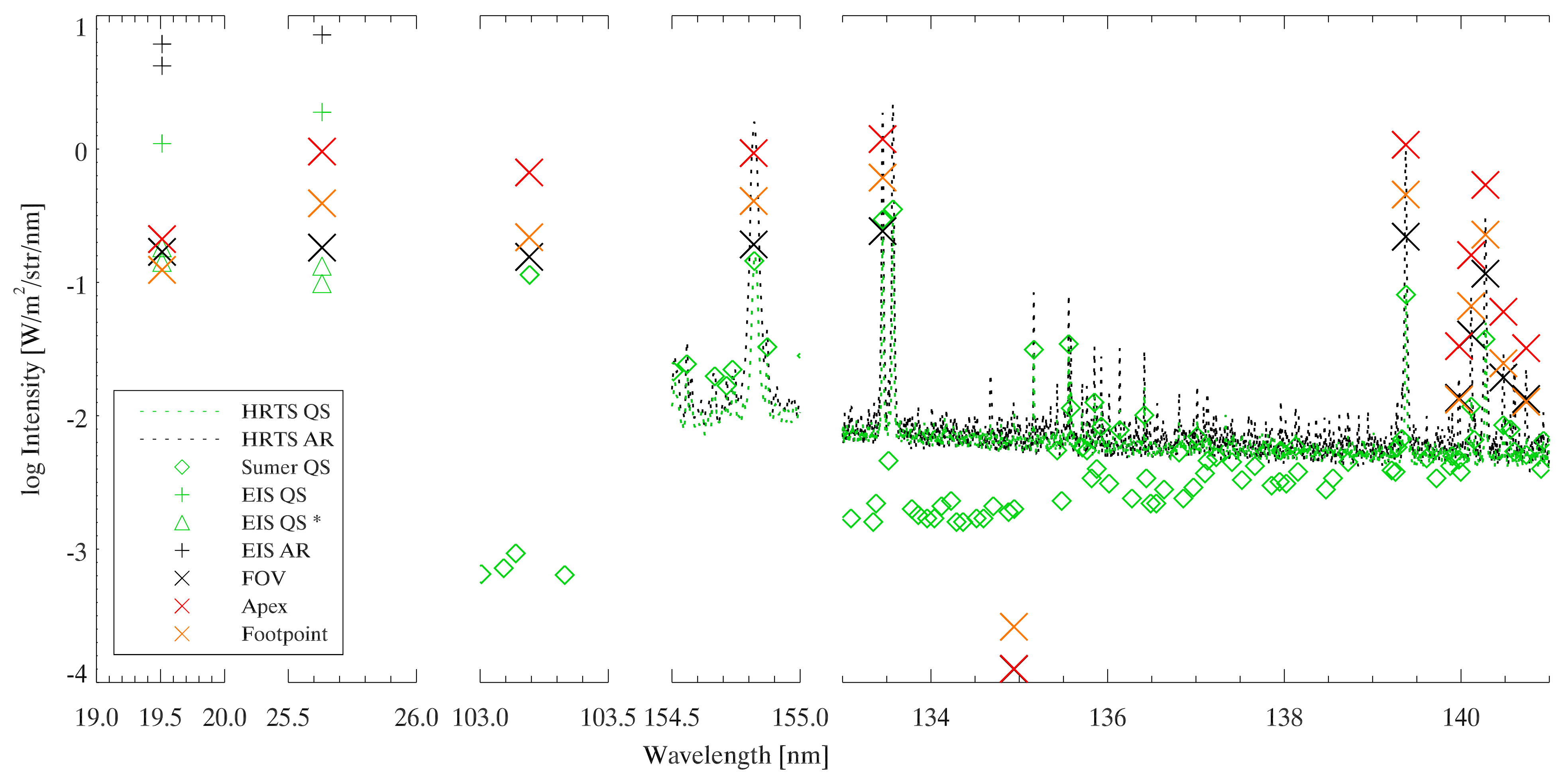
The synthetic peak intensity of the full numerical box (FNB), with the green lines indicating magnetic field lines. The orange box on the left indicate the footprint region for the magnetic field lines, and vertical field alignment. The red box in the middle indicate a region over magnetic loop apex, where the field is horizontal. The average intensity within the orange and the red boxes from the left panel are presented by the × symbol in similar color in the top right figure.



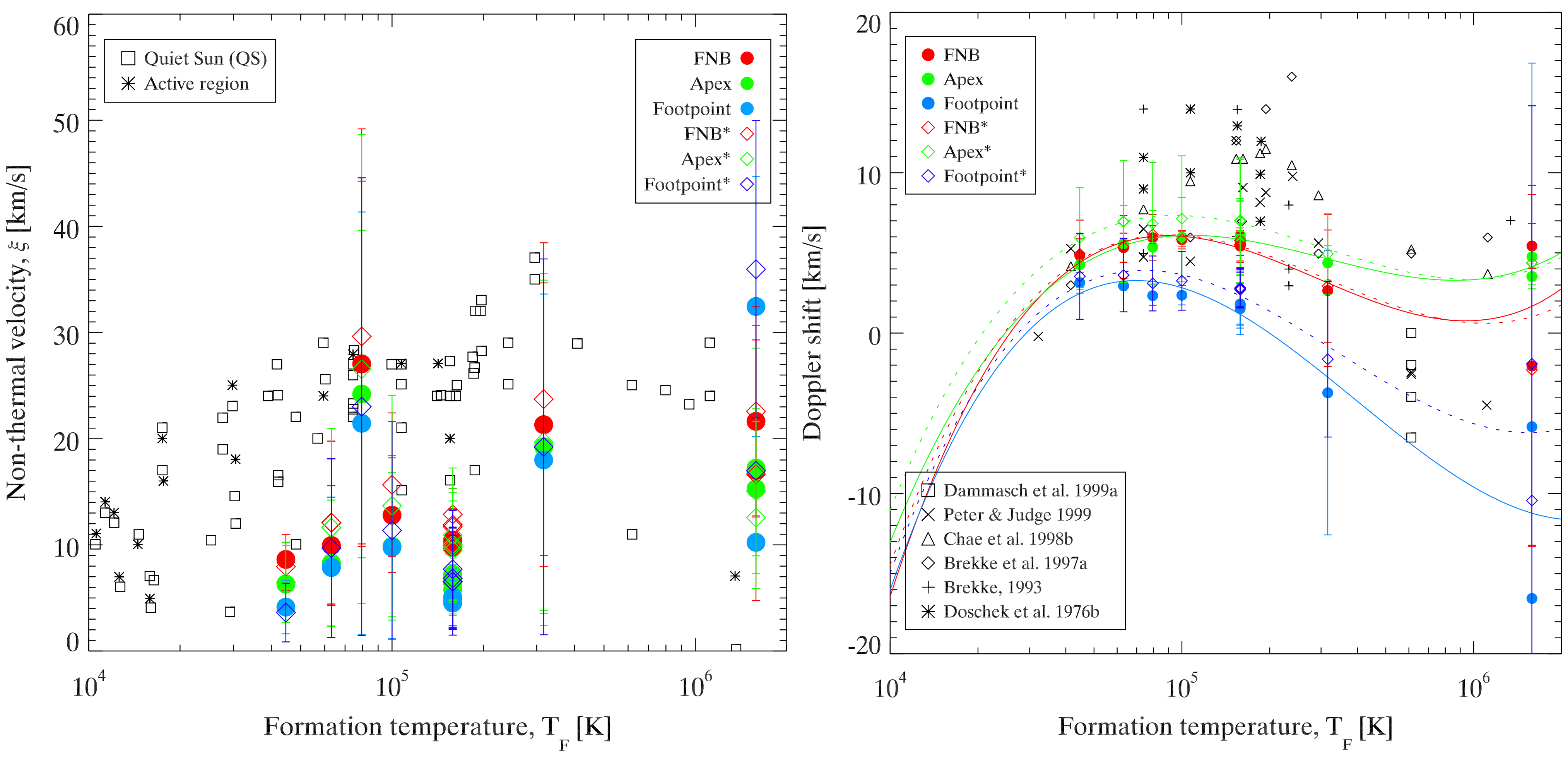
The left panel show the line ratios after we have adjusted the abundance values, while the right panel show the line ratios when using the Grevesse & Sauval (1998) abundances. The vertical dashed/dotted lines represent the ratio values from the SUMER & HRTS atlases and EIS data of Brown et al. (2008).

RESULTS

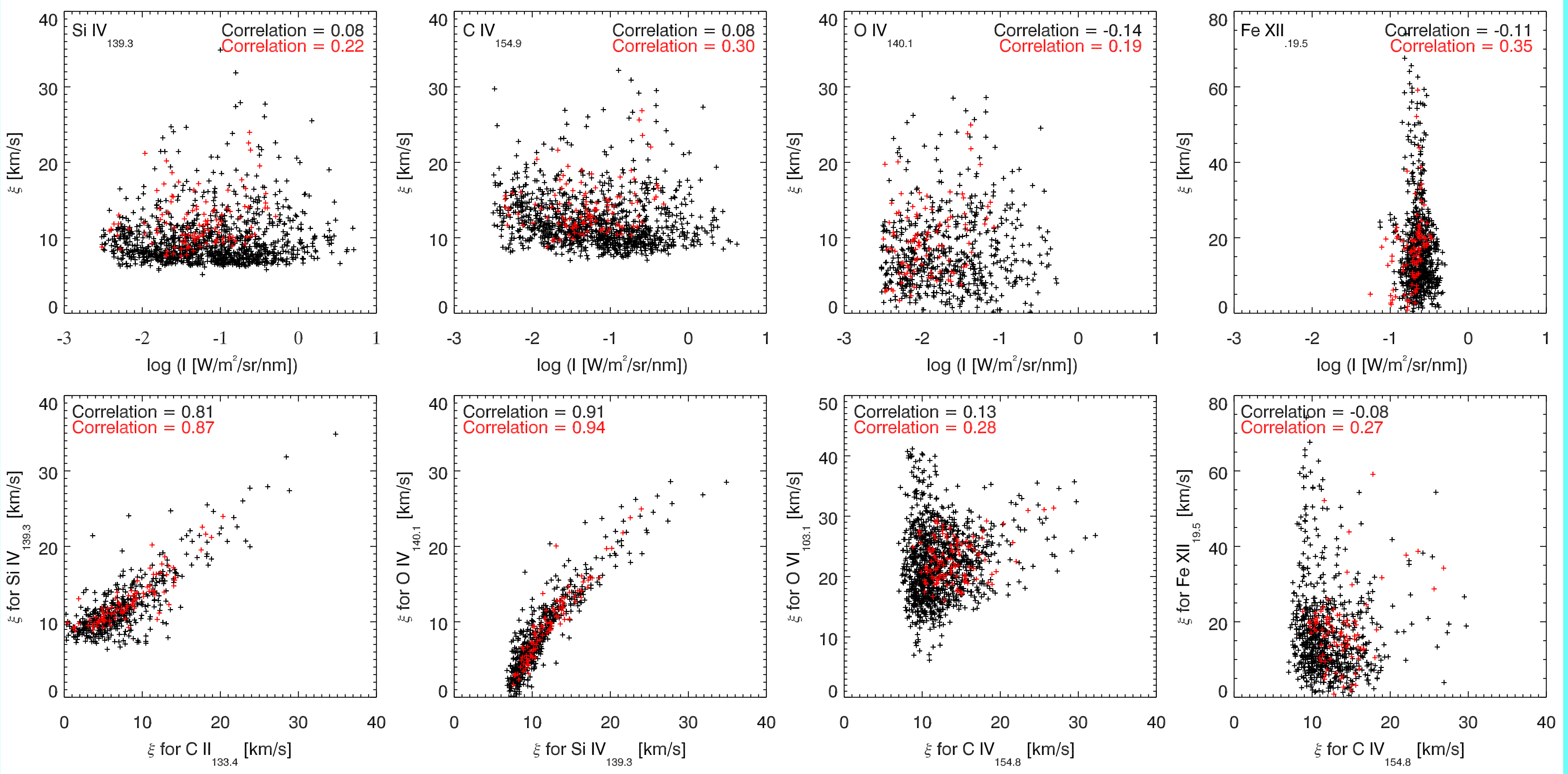
- Intensity line ratioes from the SUMER & HRTS atlases are reproduced after setting the silicon abundance to its deduced 'coronal' value Feldman(1992) and reducing the oxygen abundance to A_O=8.69 *i.e.* the Asplund et. al. (2009) value.
- The emerging synthetic intensity of the models described here are able to reproduce the observed absolute intensities to within a factor two.
- The non-thermal linewidths reproduce the well known turnoff point around 2 – 3 10^5K, but with much lower values, but are strongly dependent on resolution, and we therefore expect that the IRIS instrument with a spatial resolution of $^1/3$ will produce narrower lines on average compared to previous observations.
- The average synthetic Doppler shifts reproduce the persistent TR redshifts and blueshifts of the upper TR -corona, and are consistent with the observations. The Doppler shifts are independent of resolution.
- Intensity to non-thermal widths correlations are strongly dependent on resolution and should therefore not be used for diagnostics.



By setting the silicon abundance to its deduced `coronal' value Feldman(1992) and reducing the oxygen abundance to A_O=8.69 *i.e.* the Asplund et. al. (2009) value, the emerging synthetic intensity of the models described here are able to reproduce the observed absolute intensities to within a factor two for the most important IRIS lines formed in the TR. Using these abundance values we find that the silicon to oxygen intensity ratios lies close to that which is observed.



Comparison of the synthetic (circles) non-thermal linewidths on the left and the synthetic Doppler shifts on the right, at 1" resolution and the observed non-thermal linewidths in black (adapted from Wilhelm et al. (2007)). The diamond symbols represent the same data after applying a PSF and rebinning according to the SUMER spatial resolution reported by Chae et al. (1998).



Correlations between the intensity and non–thermal width in the top row of panel, and the ξ – ξ correlations among the lines in the bottom row of panels. The synthetic spectral data with a $1'' \times 1''$ spatial resolution is shown in black while the results obtained by convolving the data with a PSF of size $1'' \times 3''$ in the manner of Chae et al. (1998) is shown in red.Since the native data is the same, the resulting positive correlations are only an effect of the PSF and smoothing, and one should therefore be very carful when using intensity to non-thermal line width correlations between the lines for any diagnostics of the solar atmosphere.