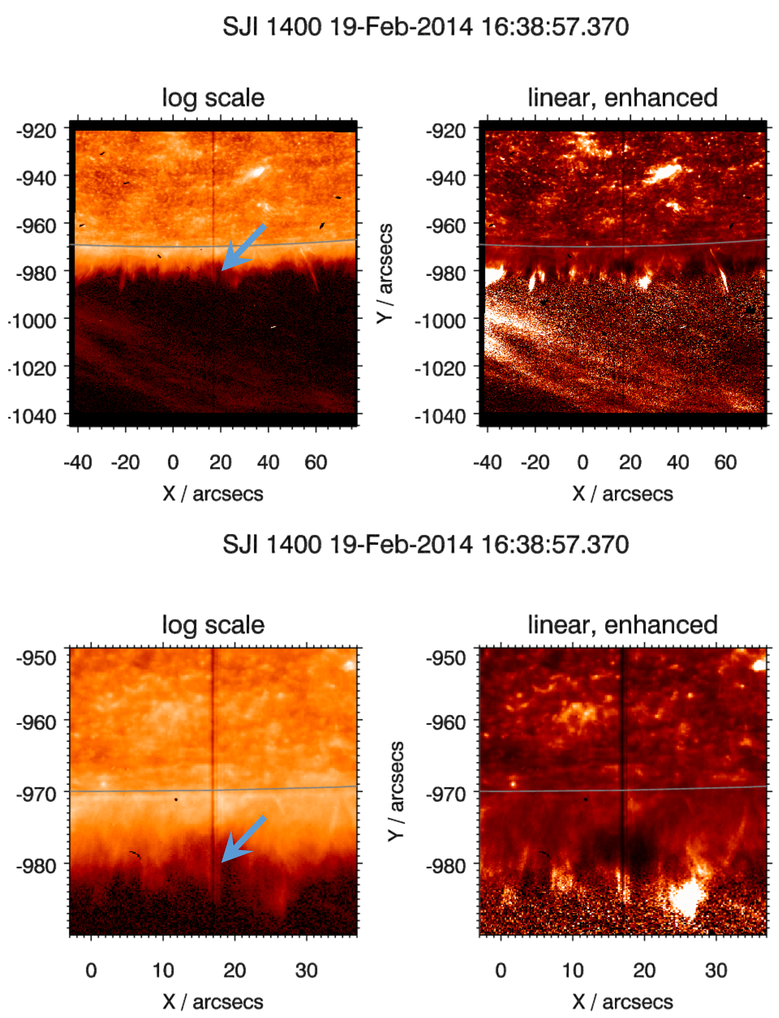
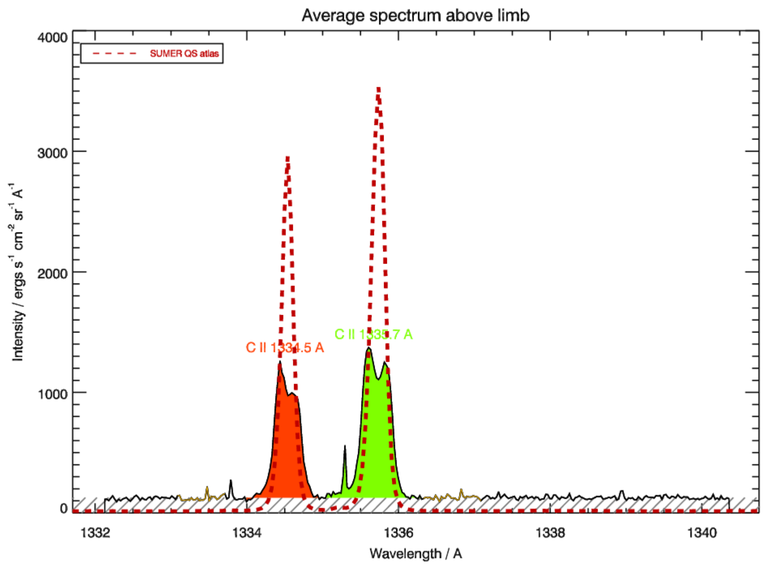
The role of type II spicules in the lower transition region

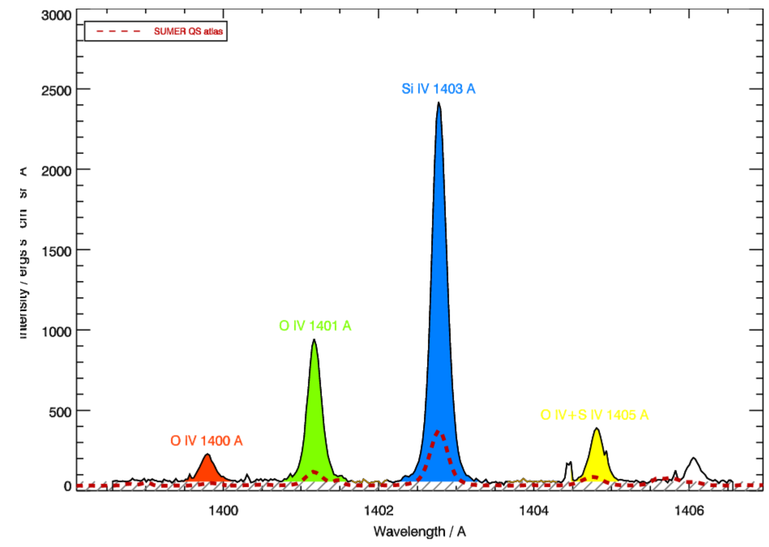
V. Andretta[1], J. Klimchuk[2], B. Fleck[3], C. Sasso[1], Th. Straus[1]

[1] INAF/OAC
[2] NASA/GSFC
[3] ESA

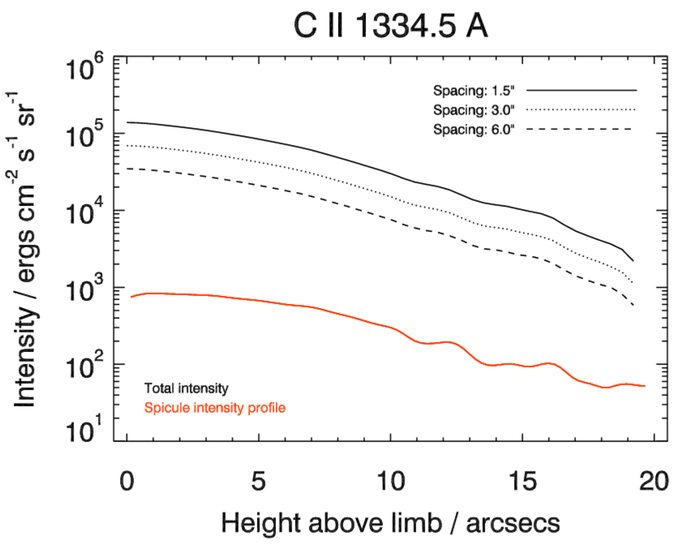


IRIS Slit jaw image at 1400 A showing the slit cutting along a type II spicule, which is indicated by an arrow





IRIS mean spectra of the Type II spicule shown in the above slit-jaw images. The quiet Sun SUMER atlas is also shown for reference.



Recent observational progress has revived the debate about the role of spicules, in particular of the faster «Type II» spicules, in the energetics and mass balance of the corona. The debate is still lively on this subject. The related issue of the role of Type II spicules in the lower transition region has so far attracted less attention, despite the long-standing problem that the various coronal heating models proposed fail to account for the radiative emission of the transition region below 10^5 K.
We are re-examining this latter issue by taking into consideration the possibility that type II spicules could explain the bulk of the observed radiative output of the lower transition region. The availability of IRIS images and spectra provide an excellent opportunity to study this problem.

We searched through a number of suitable off-limb observations, trying to characterize quantitatively the emission of Type II spicules.

In figures on the left, we show an instance of an «isolated» spicule at the south limb. The IRIS slit happens to cut longitudinally through this spicule during its short lifetime.

Spicule spectra. We examined the spectra of this spicule and derived the radial profile of line intensity vs. height for the main lines in the IRIS spectral range (the C II lines at 1335 and 1336 A, the Si IV doublet at 1393 and 1403 A, and the group of O IV and S IV lines in the range 1399 – 1406 A. A summary of the observations are shown in subsequent figures. A couple of points are worth mentioning:

- As has before been noted (Pereira et al. 2014), the emission in Si IV of Type II spicules often presents a deficit towards the limb. The same is observed for the O IV lines.

- We compared the average spicule spectra with the average quiet Sun spectrum from SUMER (Curdt et al. 2001). It is interesting to note that the hotter Si IV and O IV lines are stronger than the average disk emission, while the reverse is true for the C II lines. This might imply that the shape of the differential emission measure for Type II spicules does not match very well the observed quiet-Sun distribution. This issue will however need to be examined taking into account a statistical set of spicules.

A simple toy model In order to proceed further we considered the simple model of a «forest» of spicules, which is characterized by a «typical» emission profile as function of height of each spicule, and by an average spacing between spicules.

This simple model allows us to determine the predicted shape of off-limb emission from observed intensity profiles. A qualitative comparison is done with the average radial profiles of slit-jaw images approximately at the same time as the spectral observations.

Some points of note.

- ❑ The qualitative comparison with radial off-limb profiles is promising in the case of the Si IV lines, less so for the C II case. The CII lines, however, are often optically thick, as it is clearly shown by the average spicule spectrum.

- ❑ The fact that C II spectra are fainter than the QS atlas, whereas the hotter S IV and O IV lines are stronger, remains true even considering the toy model (integrating along the LOS does not help). This is because the height-scale of those lines are similar, and thus integrating off-limb or on-disk should not drastically change their relative intensities.

- ❑ It should be examined whether the spicule examined in detail here is really a “typical” Type II spicule. We found it just because it stands out very clearly, but its parameters are not very far from the mean values of Type II spicules (Pereira, De Pontieu, Carlsson 2012). We are currently extending the analysis to other data sets which promise to provide more spicule spectra as function of height.

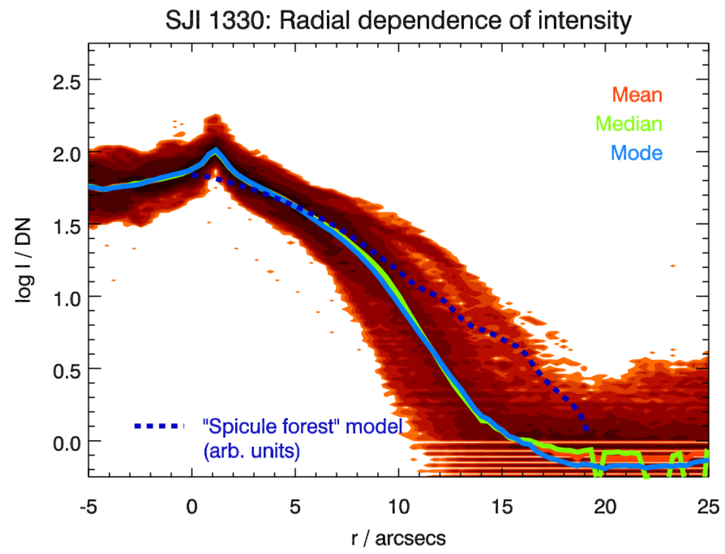
- ❑ Another point to be examined is the relation between the emission of off-limb spicules to the on-disk emission from the lower transition region.

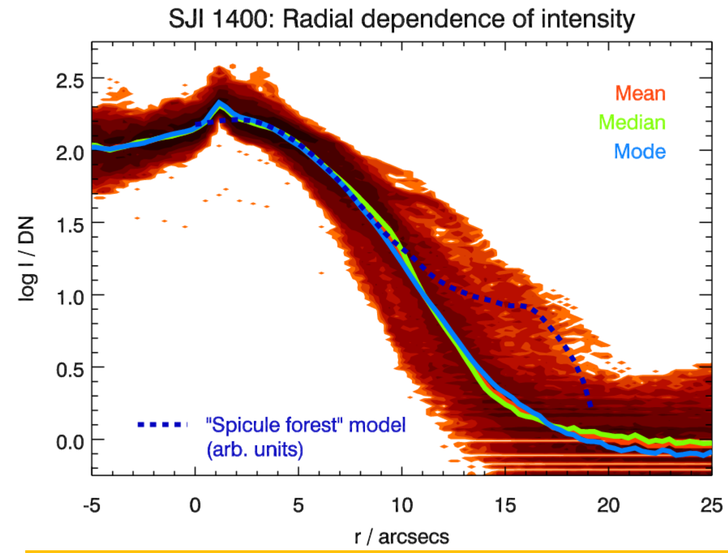
A final note: This is still a very much preliminary work, which provides some interesting clues on whether spicule emission really dominates the quiet Sun emission, at least off-limb. We however are not yet in the position to make definite statements on the issue whether the long-standing problem of the excess EUV emission in the lower TR can be attributed solely to spicule (Type II) emission.

References:

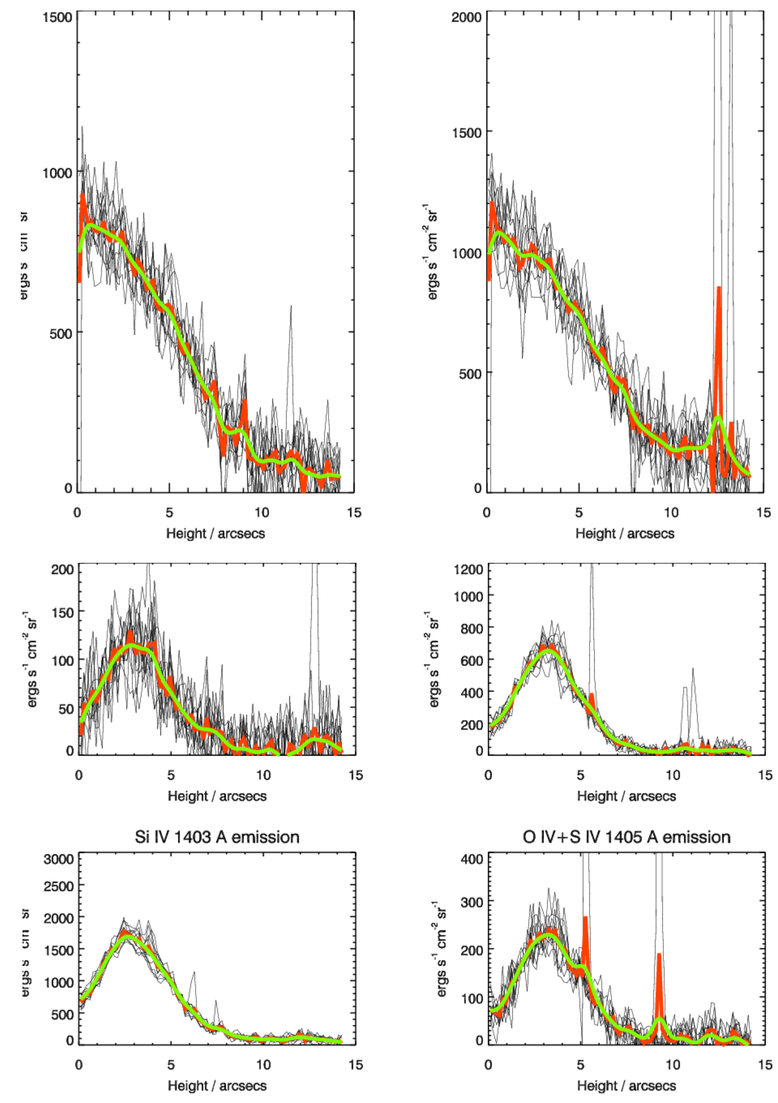
Curdt et al. (2001), A&A 375, 591
Klimchuk (2012), JGR 117, A12102
Pereira, De Pontieu, Carlsson, 2012, ApJ, 759, 18
Pereira et al. (2014), ApJ 792, L15

(***Above***) Cartoon illustrating the «spicule forest» model adopted to compute the off-limb emission from the properties of individual spicules.
(***Left***) Off-limb emission of the C II 1335 A line, for three values of the mean spacing between spicules, based on the empirical intensity profile shown in red, derived from the IRIS spectra discussed here.
(***Right***) Same profiles, for the Si IV 1403 A line.





Radial intensity profiles from IRIS Slit jaw image at 1400 A (bottom) and 1330 A (top). The mean, median and mode (peak of distribution) are shown in red, green and blue. The estimated dependence of line intensity from the IRIS line intensities shown below is also shown.



Total line intensities from IRIS spectra for a Type II spicule, as function of height above the limb. Each curve represent the intensity for a given spectrum. The red curve is the average. There curve is a smoothed version of the average curve, which is used in the «spicule forest» model.