Statistical spectroscopic analysis of quiescent prominence observed in Lyman lines by SoHO/SUMER and MgII h&k lines by IRIS

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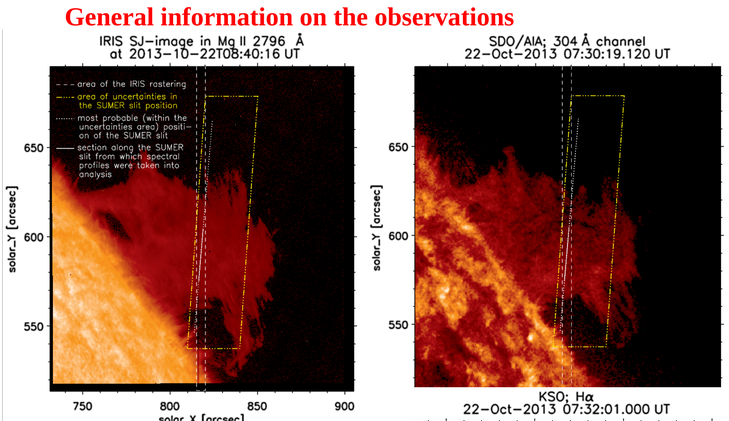
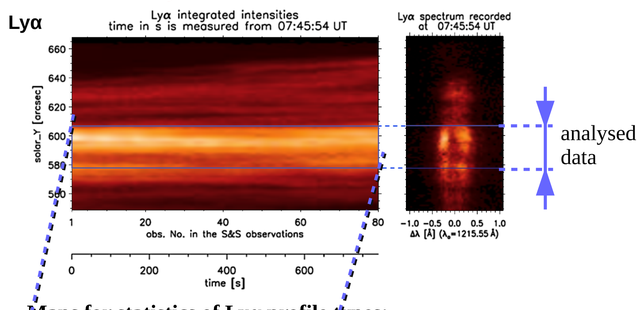
Abstract. A quiescent prominence was observed on October 22, 2013 at NW limb quasi-simultaneously and nearly co-spatially in the Lyman line series of hydrogen by SoHO/SUMER and in MgII h&k UV lines by IRIS. In this contribution we analyze a dense and compact structure of the prominence because this part is quiet and therefore suitable for quasi-static non-LTE modeling. This part of the prominence is also well visible in H_alpha filtrogram images. Spectroscopic analysis of the Lyman line and MgII h&k profiles is done using the following profile characteristics: integral intensities, depth of the central reversal and asymmetry of the peaks. Distributions of the profile characteristics within the studied area of the prominence are statistically analyzed using histograms. The profile characteristics are now defined only for profiles with one peak (purely emissive) or double-peaked. There exist also profiles with more peaks in the observed data from both instruments, thus, statistical analysis of occurrences of different type of profiles – one-, two-, three-, four-and-more-peak profiles and peculiar profiles is also made. Results of the statistical analysis of observed data are to be be compared with the analogous statistical analysis of synthetic profiles obtained using the non-LTE models of the fine structure of prominences.

General information on the observations



Rather dynamic quiescent prominence was observed on October 22, 2013 at the NW limb quasi-simultaneously and nearly co--spatially in Lyman lines of hydrogen and UV lines of MgII by two space-born spectrographs SoHO/SUMER and IRIS. FOV of the IRIS spectrograph dense rastering (composed of 16 slit positions with the step of 0.35 arcsec) and position of the SUMER slit within its uncertainties during its sit-and-stare (S&S) observations are shown in the IRIS MgII 2796 Å SJ image, cut-off from the SDO/AIA 304 Å full--disc image and cut-off of the Hα filtergram from KSO. As there is rather large uncertainty in position of the SUMER slit, spectroscopical analysis of data from the two spectrographs are made individually and then the results are compared. Only compact and dense part of the prominence, visible also in the Hα filtergram, is analysed due to lower dynamics occurring there and therefore profiles from this parts are more suitable for our future non-LTE modelling.

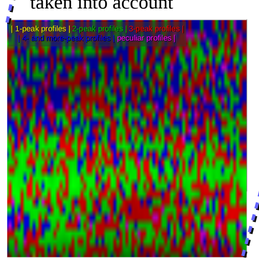
Sit-and-stare Lyman line observations of SUMER

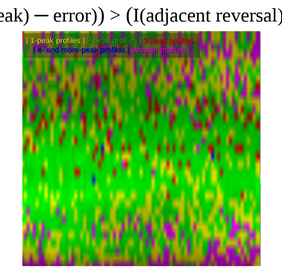


Maps for statistics of Lyα profile types:
1-peak profiles 2-peak profiles 3-peak profiles
4- and more peak profiles peculiar profiles

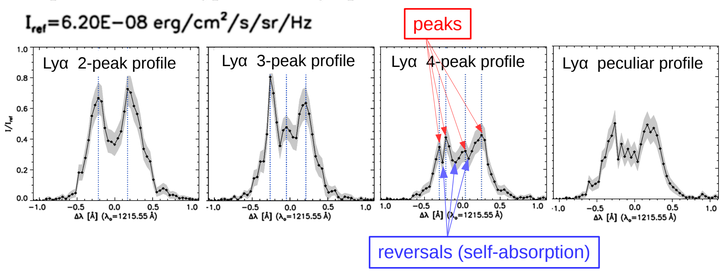
all peaks in profiles taken into account

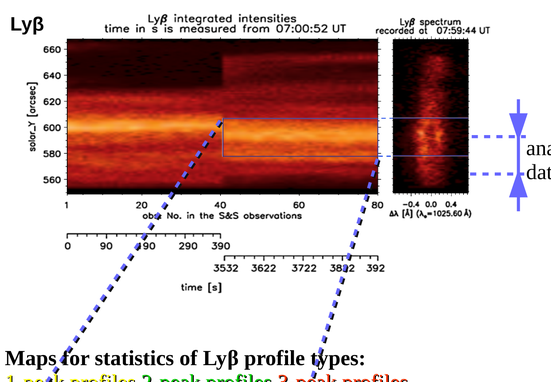
only peaks not lost in errors taken into account, that is (I(peak) – error)) > (I(adjacent reversal) + error)





Examples of the four types of the Lyα profiles:

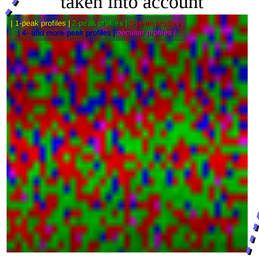


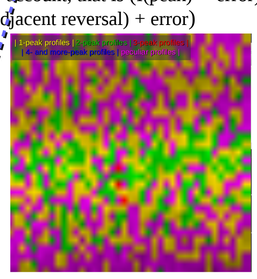


Maps for statistics of Lyβ profile types:
1-peak profiles 2-peak profiles 3-peak profiles
4- and more peak profiles peculiar profiles

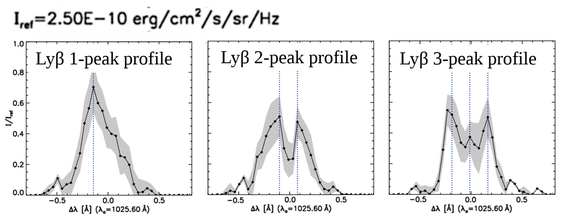
all peaks in profiles taken into account

only peaks not lost in errors taken into account, that is (I(peak) – error) > (I(adjacent reversal) + error)

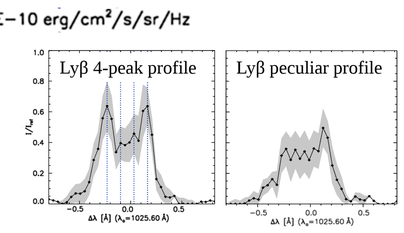




Examples of the five types of the Lyβ profiles:



Examples of the five types of the Lyβ profiles … continuation



The Lyγ and Lyδ line SUMER spectra and subsequently profiles from the analysed part of the prominence are very similar to those of Lyβ. Also maps of profile types for the two lines are similar to those for Lyβ.

Summary of results of profile type statistics for the H Lyman lines

Lyα
– all profiles in the studied area of the prominence: 240
– all 1-peak profiles: none (0 % of all profiles in the studied area)
– 1-peak profiles including also 2- and more-peak profiles in which only one peak is not lost in errors: 718 (30 % of all profiles in the studied area)
– all 2-peak profiles: 905 (38 % of all profiles in the studied area)from which only 728 (30 % of all profiles in the studied area) have both peaks not lost in error
– 2-peak profiles including also 3- and more-peak profiles in which only two peaks are not lost in errors: 1272 (53 % of all profiles in the studied area)
– all 3-peak profiles: 866 (36 % of all profiles in the studied area), from which 59 (3 % of all profiles in the studied area) have all three peaks not lost in errors and 374 (16 % of all profiles in the studied area) have two peaks of the three not lost in errors
– 3-peak profiles including also 4-and-more-peak profiles in which 3 peaks are not lost in errors: 103 (4% of all profiles in the studied area)
– all 4-&more-peak profiles: 563 (23 % of all profiles in the studied area)
– peculiar profiles: 66 (3 % of all profiles in the studied area) peculiar profiles including 2- and more-peak profiles with all peaks lost in errors: 238 (10 % of all profiles in the studied area)

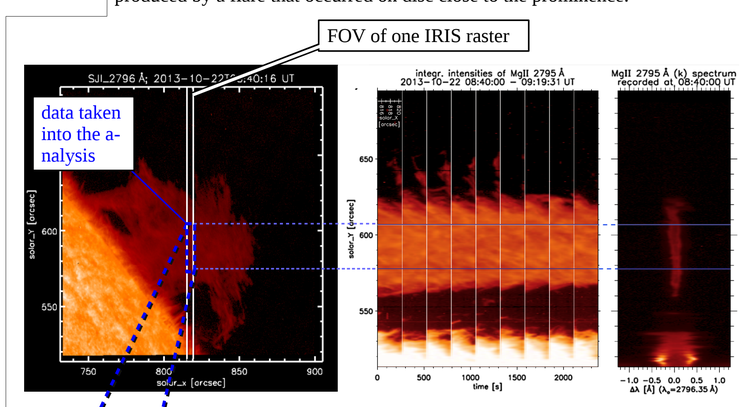
Lyβ
– all profiles in the studied area of the prominence: 120
– all 1-peak profiles: 1 (much less than 1 % of all profiles in the studied area)
– 1-peak profiles including also 2- and more-peak profiles in which only one peak is not lost in errors: 476 (40 % of all profiles in the studied area)
– all 2-peak profiles: 503 (42 % of all profiles in the studied area), from which only 150 (12 % of all profiles in the studied area) have both peaks not lost in errors
– 2-peak profiles including also 3- and more-peak profiles in which only two peaks are not lost in errors: 217 (18 % of all profiles in the studied area)
– all 3-peak profiles: 505 (42 % of all profiles in the studied area), from which only 3 (less than 1 % of all profiles in the studied area) have all three peaks not lost in errors and 60 (5 % of all profiles in the studied area) have two peaks of the three not lost in errors
– 3-peak profiles including also 4-and-more-peak profiles in which 3 peaks are not lost in errors: 3 (less than 1 % of all profiles in the studied area)
– all 4-&more-peak profiles: 145 (12 % of all profiles in the studied area)

Lyγ
– all profiles in the studied area of the prominence: 1200
– all 1-peak profiles: 14 (1 % of all profiles in the studied area)
1-peak profiles including also 2- and more-peak profiles in which only one peak is not lost in errors: 430 (36 % of all profiles in the studied area)
– all 2-peak profiles: 590 (49 % of all profiles in the studied area), from which 111 (9 % of all profiles in the studied area) have both peaks not lost in errors
2-peak profiles including also 3- and more-peak profiles in which only two peaks are not lost in errors: 170 (14 % of all profiles in the studied area)
– all 3-peak profiles: 422 (35 % of all profiles in the studied area), from which only 1 (much less than 1% of all profiles in the studied area) have all three peaks not lost in errors and 44 (4 % of all profiles in the studied area) have at least two peaks not lost in errors
3-peak profiles including also 4-and-more-peak profiles in which 3 peaks are not lost in errors: 1 (much less than 1 % of all profiles in the studied area)
– all 4-&more-peak profiles: 161 (13 % of all profiles in the studied area)
– peculiar profiles: 13 (1 % of all profiles in the studied area)
peculiar profiles including 2- and more-peak profiles with all peaks lost in errors: 586 (49 % of all profiles in the studied area)

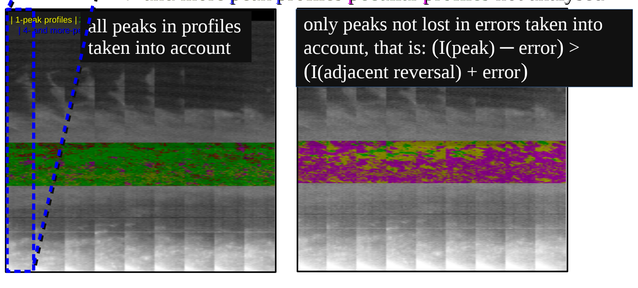
Lyδ
– all profiles in the studied area of the prominence: 1200
– all 1-peak profiles: 37 (3% of all profiles in the studied area)
1-peak profiles including also 2- and more-peak profiles in which only one peak is not lost in errors: 404 (34% of all profiles in the studied area)
– all 2-peak profiles: 463 (39% of all profiles in the studied area), from which 62 (5% of all profiles in the studied area) have both peaks not lost in errors
– 2-peak profiles including also 3- and more-peak profiles in which only two peaks are not lost in errors: 162 (13% of all profiles in the studied area
– all 3-peak profiles: 297 (25% of all profiles in the studied area), from which 7 (less than 1% of all profiles in the studied area) have all three peaks not lost in errors and 39 (3% of all profiles in the studied area) have at least two peaks not lost in errors
– 3-peak profiles including also 4-and-more-peak profiles in which 3 peaks are not lost in errors: 19 (2% of all profiles in the studied area)
– all 4-&more-peak profiles: 340 (28% of all profiles in the studied area)
– peculiar profiles: 63 (5% of all profiles in the studied area)
– peculiar profiles including 2- and more-peak profiles with all peaks lost in errors: 551 (46% of all profiles in the studied area)

Dense rasters composed of 16 slit positions made by IRIS in the MgII h &k lines

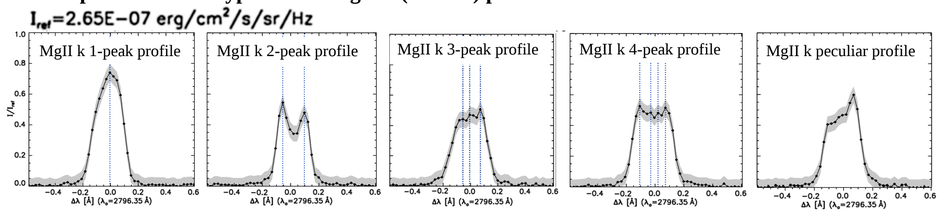
Data from nine rasters (08:40 – 08:42 UT) only of all 31 were taken into the analysis due to the fact that later data were affected by impacts of particles produced by a flare that occurred on disc close to the prominence.



Maps for statistics of MgII k (2796 Å) profile types:
1-peak profiles 2-peak profiles 3-peak profiles
4- and more peak profiles peculiar profiles not analysed



Examples of the five types of the MgII k (2796 Å) profiles:



For the MgII h (2803 Å) line similar maps of profile types were obtained.

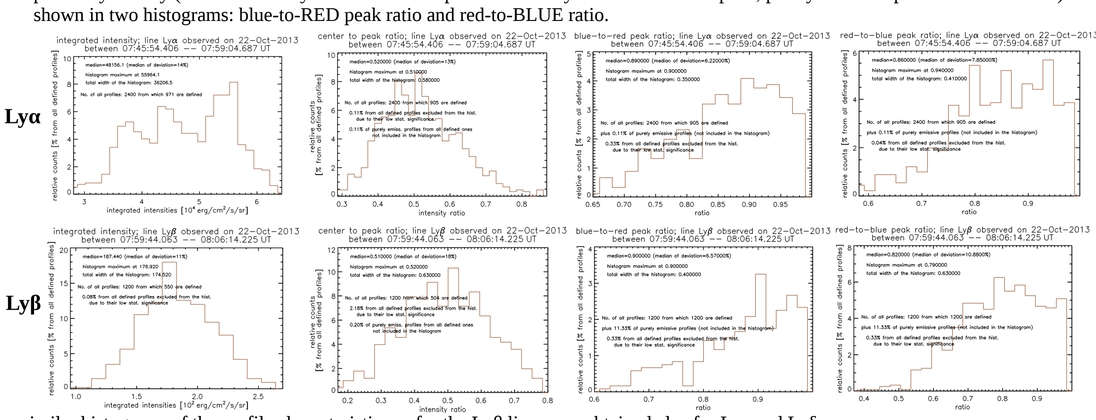
Summary of results of profile type statistics for the MgII h&k lines

MgII k (2796 Å)
– all profiles in the studied area of the prominence: 25632
– all 1-peak profiles: 2973 (12% of all profiles in the studied area)
1-peak profiles including also 2- and more-peak profiles in which only one peak is not lost in errors: 9912 (39% of all profiles in the studied area)
– all 2-peak profiles: 18191 (71% of all profiles in the studied area), from which only 1136 (4% of all profiles in the studied area) have both peaks not lost in errors
– 2-peak profiles including also 3- and more-peak profiles in which only two peaks are not lost in errors: 1166 (5% of all profiles in the studied area)
– all 3-peak profiles: 2706 (11% of all profiles in the studied area), from which none (0% of all profiles in the studied area) have all three peaks not lost in errors and 30 (less than 1% of all profiles in the studied area) have two peaks of the three not lost in errors
3-peak profiles including also 4-and-more-peak profiles in which 3 peaks are not lost in errors: 0 (0% of all profiles in the studied area)
– all 4-&more-peak profiles: 115 (less than 1% of all profiles in the studied area)
– peculiar profiles: 1647 (6% of all profiles in the studied area)
peculiar profiles including 2- and more-peak profiles with all peaks lost in errors: 12907 (50% of all profiles in the studied area)

MgII h (2803 Å)
– all profiles in the studied area of the prominence: 25632
– all 1-peak profiles: 5073 (20% of all profiles in the studied area)
1-peak profiles including also 2- and more-peak profiles in which only one peak is not lost in errors: 8354 (33% of all profiles in the studied area)
– all 2-peak profiles: 16125 (63% of all profiles in the studied area), from which only 142 (less than 1% of all profiles in the studied area) have both peaks not lost in errors
2-peak profiles including also 3- and more-peak profiles in which only two peaks are not lost in errors: 148 (less than 1% of all profiles in the studied area)
– all 3-peak profiles: 3042 (12% of all profiles in the studied area), from which none (0% of all profiles in the studied area) have all three peaks not lost in errors and 6 (much less than 1% of all profiles in the studied area) have two peaks of the three not lost in errors
– 3-peak profiles including also 4-and-more-peak profiles in which 3 peaks are not lost in errors: 0 (0% of all profiles in the studied area)
– all 4-&more-peak profiles: 154 (less than 1% of all profiles in the studied area)
– peculiar profiles: 1238 (5% of all profiles in the studied area)
peculiar profiles including 2- and more-peak profiles with all peaks lost in errors: 15892 (62 % of all profiles in the studied area)

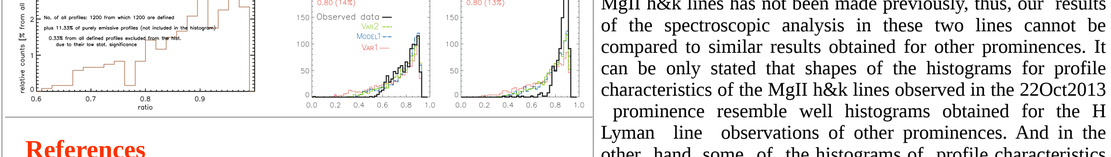
Statistics of the profile characteristics of the H Lyman lines and MgII h&k lines

- Only 1- and 2-peak profiles taken into the analysis
- Three profile characteristics are used: integrated intensity with purely emissive profiles (1-peak profile) included, ratio of the intensity in the reversal (central self-absorption) to average intensities from the peaks (purely emissive profiles are excluded) and peaks asymmetry (ratio of intensity in less intensive peak to intensity in more intensive peak, purely emissive profiles are excluded) shown in two histograms: blue-to-RED peak ratio and red-to-BLUE ratio.



– similar histograms of the profile characteristics as for the Lyβ line were obtained also for Lyγ and Lyδ
– for integrated intensity similar histograms were obtained when also other profiles (with 3 and more peaks and also peculiar) were included)

MgII k (2796 Å)



– similar histograms were obtained for the MgII h (2803 Å) line, with only difference that maximum of histogram of integral intensities was at the value 14200 erg/cm2/s/sr but the shape of the histogram is very similar to that for the MgII h line.

Comparison of the results of the spectroscopic analysis in the H Lyman lines with results obtained for another quiescent prominences

- histogram of integr. intensities of Lyα has more than one peak similarly as it was for the prominence observed on 15 May 2015 where structures containing plasma in different physical conditions are projected together on limb. Values of integrated intensities are higher in 22Oct2013 prominence than in the prominence observed by SUMER in 15May2005 (Schwartz et al. 2015)

22Oct2013 prominence

15May2005 prominence

Histograms of asymmetry of peaks of the Lyman line profiles for the 22Oct2013 prominence have maximum at lower values than it was for previously studied prominences:

22Oct2013 prominence

prominence observed on 25 and 26 May 2005

- histograms of integr. intensities of Lyα and Lyβ for the 22 Oct 2013 prominence are comparable to values in the hi- stogram obtained for the prominence observed on 26 and 26 May 2005.

22Oct2013 prominence

prominence observed on 25 and 26 May 2005

(Gunár et al. 2010)

Label	Set of input parameters Common to all models	
Model1	$T_0 = 7000$ K; $T_w = 100\,000$ K; $B_x(0) = 6$ Gauss; $p_0 = 0.015$ dyn cm^{-2}; $M_0 = 1.1 \times 10^{-4}$ g cm^{-2}	$\gamma_1 = 10$, $\gamma_2 = 60$
Var1		$\gamma_1 = 5$, $\gamma_2 = 30$
Var2		$\gamma_1 = 10$, $\gamma_2 = 30$

Conclusions

Non-LTE modelling of the prominence fine structure in the MgII h&k lines has not been made previously, thus, our results of the spectroscopic analysis in these two lines cannot be compared to similar results obtained for other prominences. It can be only stated that shapes of the histograms for profile characteristics of the MgII h&k lines observed in the 22Oct2013 prominence resemble well histograms obtained for the H Lyman line observations of other prominences. And in the other hand, some of the histograms of profile characteristics of the H Lyman lines observed in the 22Oct2013 prominence differ much in shape from the histograms obtained for H Lyman line observations of other prominence. The detectors of the SUMER spectrograph could be already affected by agingin the year 2013, thus, comparison of result of the non-LTE modelling of observations made by the both SUMER and IRIS spectrographs can show also whether the SUMER observations from that time are still usable.

References

Gunár, S., Schwartz, P., Schmieder, B., Heinzel, P., Anzer, U. 2010, A&A 514, A43
Schwartz, P., Gunár, S., Curdt, W., 2015, A&A 577, A92

Acknowledgement

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