Statistical analysis of IRIS compact bursts

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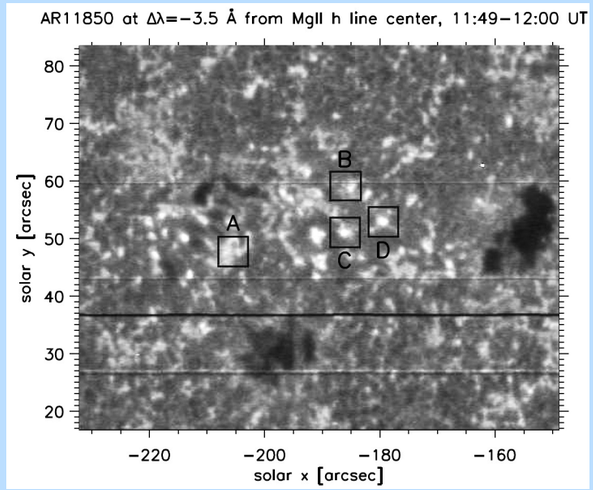
ABSTRACT

Compact bursts (CBs) are frequently observed by IRIS in both NUV and FUV channels. They appear as small and intense short-time brightenings visible in solar active regions. We present the statistical analysis of active regions with emerging flux areas based on the IRIS observations in Mg II h and k lines. We used dense and large rasters for searching of compact bursts with the size of the order of 1". Only brightennings with the intensity contrast greater than 2 (in Mg II h line wings at -3,5Å) or with strong k line emission (with contrast greater then 6.5 in the range (-1.5Å, +1.5Å) were chosen for the analysis. Using Mg II h and k line profiles for all brightening we run statistical analysis of some parameters of the line profiles: peak intensities, peak ratio, line center intensity and contrast in characteristic profiles points. This analysis allows us to categorize bursts in the way as it was done in Grubecka et al. (2016). We also searched for correlations between the emission of Mg II lines and hotter Si IV and C II lines in order to find which of events are linked with IRIS bombs.



IRIS observations of the AR 11850 – spectroheliograms in the Mg II line wing reconstructed at 2800.0 Å (from Grubecka et al 2016). Several CBs visible in the FOV.

IRIS DENSE AND LARGE RASTERS

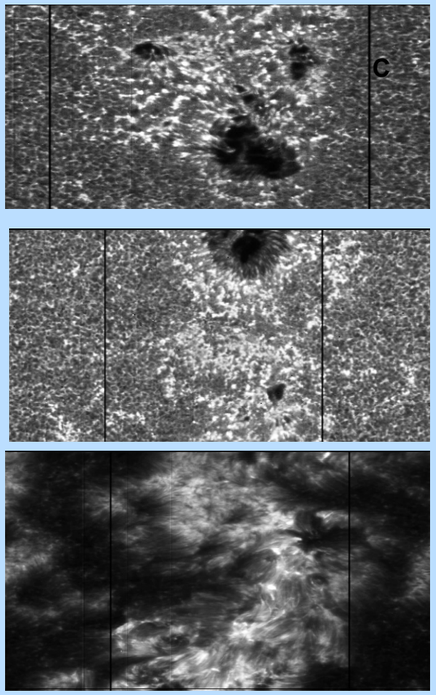
Our paper published in 2016 (Grubecka et al.), in which we modelled 5 different selected compact bursts visible in Mg II h and k lines initiates our interesting in low atmosphere small scale events, its diversity and possible connection to Ellerman Bombs, IRIS bombs and both simultaneously.

Our present aims is to investigate statistically diversity of Mg II h and k lines of compact phenomena (CBs) and its visibility in far UV lines such as Si IV, C II and in Mg II triplet. In order to achieve goals in IRIS database we searched for dense rasters of active and emerging flux region containing spectra in Mg II, C II, Si IV. Totally, we found **184 rasters** observed between 2013 and 2018.

We constitute 3 search criteria based on contrast in different wavelengths and the automatic procedure found 2950 compact bursts (CBs) in 184 rasters. Some of the CBs were removed after visual verification and finally we used **2776 CBs**.

These 3 searching criteria can be summarized:

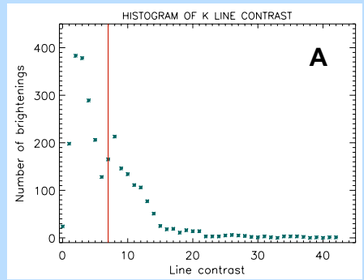
1) brightenings with greater then 2 contrast at 2800Å: **1835 EVENTS FOUND**
2) brightenings with greater then 10 contrast in integrated and averaged intensity of Mg II k line in range -1.5, +1.5 Å): **404 EVENTS FOUND**
3) brightenings with greater than 6.5 contrast in Mg II k line and simultaneously greater then 1.4 contrast at 2800Å: **537 EVENTS FOUND**

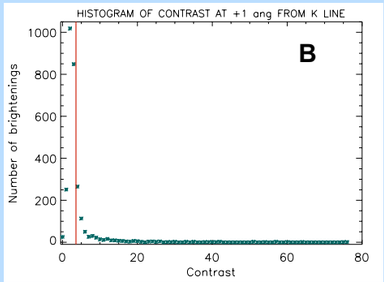


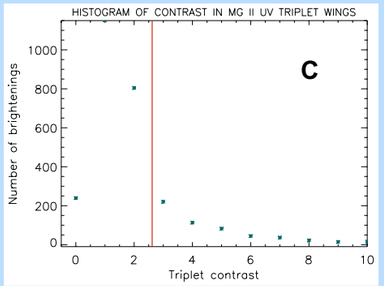
Example of IRIS dense rasters. Emerging flux region at Feb 4, 2016 (up) and at Feb 8, 2018. Two upper spectro-heliograms are reconstructed in the Mg II line wing at 2800.0Å. The lower one in Mg II k line center

PARAMETERS OF THE MG II K LINE

First step was to calculate for each profile a set of parameters, which help us define, describe and compare each events.
Parameters:
I_C - Line center intensity contrast
I_P - Peak average intensity contrast
I_L - Line intensity contrast
I_{+1A} - Contrast at +1Å from k line
I_{2800A} - Contrast at 2800 Å
I_{TUV} - Average contrast of Mg II triplet wings







Histograms of contrast of all 2776 CBs for the Mg II k line integrated from -1Å to +1Å (A), line wing at +1Å (B), and Mg II triplet line (C). The contrast of CBs was calculated with respect to the QS according to the formula: $C=(I_{CB} - I_{QS})/I_{QS}$

CLASSIFICATION OF COMPACT BURSTS

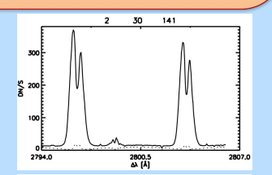
Taking into account the results of our previews modelling, we divided all CBs in 3 types based on Mg II line properties, in similar way as in our paper (Grubecka et al. 2016). This division reflects formation heights for each brightening in the following way:

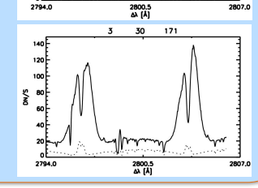
Type 1 – CBs forming higher in the chromosphere, strong emission only in Mg II line peaks;
Type 2 – CBs forming lower, with emission observed both in the line peaks and line wings;
Type 3 – CBs showing emission only in far wings of Mg II h and k lines, therefore forming close to the photosphere

Our classification of CBs is based on the relation between emission in the wing of k line (at 2800Å) and emission in the k line in the range 2795.35–2797.35Å.

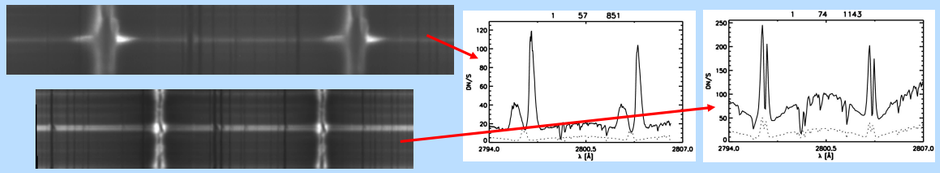
We found that 35% (986) of CBs belong to Type 1, 46% (1281) to Type 2 and 19% (509) to Type 3. Below we present some examples of the Mg II k profiles for CBs of all three types:

EXAMPLES OF TYPE 1 CBs (totally 986 events)

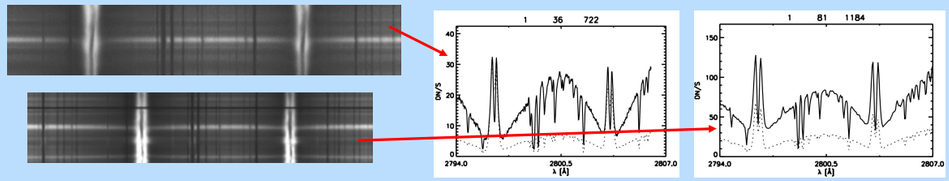




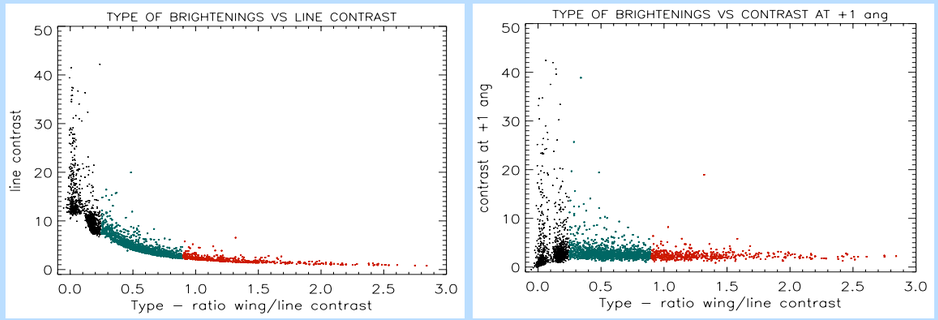
EXAMPLES OF TYPE 2 CBs (totally 1281 events)



EXAMPLES OF TYPE 3 CBs (totally 509 events)



CORRELATIONS BETWEEN PROFILES PARAMETERS

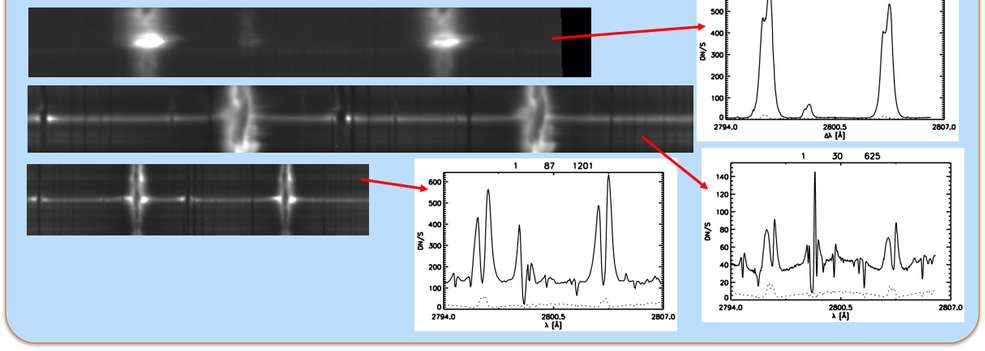


Left: Correlation plots showing the dependence of the contrast in the line center (C_L) versus ratio of the contrast in far wing to contrast in the line center (C_W/C_L); Right: dependence of the contrast in the line wing at +1Å (C_{1A}) versus ratio of the contrast in far wing to contrast in the line center (C_W/C_L). Colors of dots correspond to different types of CBs: **Black: Type 1, Blue: Type 2, Red: Type 3.**

MG II TRIPLET

Triplet Mg II UV emission in 2798.8 Å line occurs mainly for strong CBs events with strong emission in h and k lines (strong peaks), but not for events with emission only in far wings. We often observe emission in wings of the Mg II triplet lines (but with absorption in center 2798.8 A), more frequently for CBs of Type 1 and 2. Around 50% of all phenomena has emission in triplet wings larger then for wings at 2800 Å). **Around 72% of CBs of Type 1 exhibit also increased emission in Mg II triplet. For Type 2 it is 43%, and for Type 3 only 28% of CBs show strong emission in Mg II triplet.** There are also some CBs among Type 1 with strong peaks emission in h and k lines and additional emission in UV triplet lines, but without absorption in center. Our goal is to examine in which events exactly this emission occurs. We are interested in looking for correlation with other profiles parameters. The fact that emission in wings or center of the triplet lines appears accidentally in similar events may suggest different formation mechanism for them.

EXAMPLES OF CBs EVENTS WITH STRONG EMISSION IN MG II TRIPLET



Si IV and C II EMISSION

Vissers et al. 2015, Tiian et al. 2016 presented evidences for emission both in Mg II h and k lines and in Si IV, with suggestion that this simultaneous emission appears only for strong events, in the case of low height formation in solar atmosphere. Our goal is to investigate for which events, especially for which type of them we can observe simultaneous emission in Mg II, SI IV and C II line. In many cases we can see similarities in shapes of these all profiles, which appear in similar general shape, proportion and asymmetry of the profiles.

- **All CBs events which has no emission in Mg II k line, but only in wings, there is no emission in Si IV and C II.**
- **From our 2776 CBs, 1356 have emission in Si IV line and 2187 show response in C II lines.**
- **1353 (49%) from all events have emission both in Si IV and C II.**

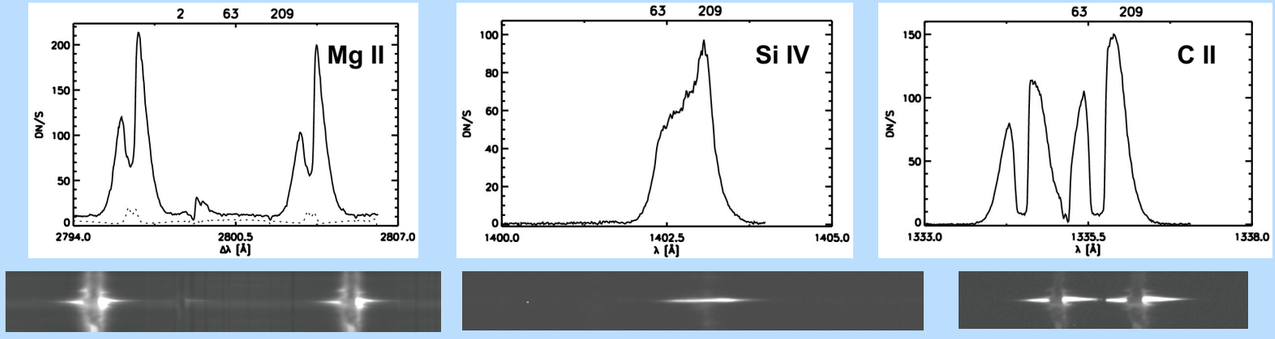
Different types of CBs exhibit different fraction of Si IV and C II emission:

- **Type 1 has 986 events, 842 (85%) with emission in SI IV and 968 (98%) with emission in CII**
- **Type 2 has 1281 events, 460 (36%) with emission in SI IV and 1017 (79%) with emission in CII**
- **Type 3 has 509 events, 54 (11%) with emission in SI IV and 202 (40%) with emission in CII**

We have also investigated asymmetries of the line profiles:

- **From CBs showing emission in Mg II k and in Si IV, 703 of them present the same type of asymmetry (52%);**
- **From CBs with emission in Mg II k and C II line, 1049 of them have the same type of asymmetry (48 %);**
- **644 among this events (47%) has the same type of asymmetry in all three lines (Mg II k , Si IV, C II)**

EXAMPLES OF CBs EVENTS WITH THE SAME TYPE OF ASYMMETRIES IN Mg II, Si IV and C II lines



Different characteristics of FAR UV emission of CBs

ANALYZE CHARACTERISTIC	NUMBER OF EVENTS
Emission in Si IV	1356 (49%)
Emission in C II	2187 (79%)
Both emission (Si IV and CII)	1353 (49%)
Red wing assymetry for Mg II k line	927
Red wing assymetry for CII line	1064
Red wing assymetry for Si IV line	703
Blue wing assymetry for Mg II k line	895
Blue wing assymetry for CII line	837
Blue wing assymetry for Si IV line	548
None assymetry Mg II k line	954
None assymetry C II line	174
None assymetry Si IV line	105
Same assymetry for Mg II and CII	1049
Same assymetry for Mg II and Si IV	703
Same triple assymetry for all lines	644

SUMMARY

In this preliminary work we analyzed basic characteristics of 2776 CBs. In particular, the relations between Mg II and hotter Si IV and C II lines were analyzed. It is interesting to notice that the CBs with strong emission in Mg II lines has also strong emission in Si IV and C II lines. This suggests that CBs located higher in solar atmosphere affect also the Transition Region plasma. The collected material contains a lot of information which will be progressively analyzed. We hope to learn about the formation and location of different types of CBs. Theoretical modelling of the lines observed in CBs will provide a better constraints on the temperature, plasma density and dynamics of CBs.

References

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Poster

4. Eruptions in the solar atmosphere

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