Statistical investigation of low atmospheric response during flares using the multi-wavelengths observations by IRIS, Hinode, and SDO

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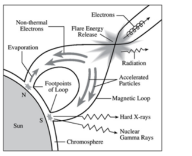
Abstract

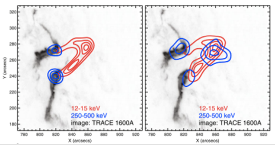
When a are occurs, we can observe solar plasma response in multi-wavelengths from optical to HXR. Especially, some strong ares produce white light emissions, white light (WL) flares, and are ribbons are observed in the low atmosphere. To understand how the energy transports to the low atmosphere and how the low atmosphere responses to the solar flares, we investigated the UV and EUV spectral lines and WL continuum images statistically. We have investigated the Mg II triplet, Si IV emission and WL continuum in 60 M and X class flares, which detected by the IRIS, SDO/HMI and Hinode/SOT from 2014 to 2016. From the analysis, we have found that the Mg II triplet mostly becomes emission during flares along the are ribbons and footpoints of the flaring loop region, which indicates that the low atmospheric heating. At the same time, we also examined the Doppler velocity of the Si IV emission, and mostly they show the red-shifted emission (40 km s^{-1}) correlated in time and location of the Mg II triplet emission. WL continuum also enhanced during several flares (17 flares), but not in all the flares. By comparison between the Mg II triplet and WL continuum, we also discuss the energy transport process, such as thermal conduction, electron beam, or Alfvn wave, in the ares with/without WL flares.

I. Introduction

I.1 White light flare

- Standard flare model

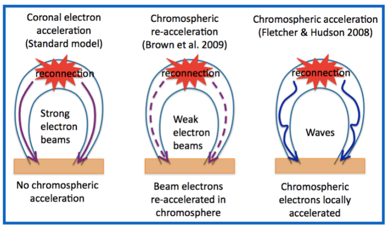




Krucker et al. (2008)

- Strong flares produce white light continuum, White light flare (WLF).
- HXR – WLF correlation suggests that flare-eccelerated electrons are involved in the production of the WL emission
- It is still unclear how the energy is transported to the low atmosphere and produces the WLFs

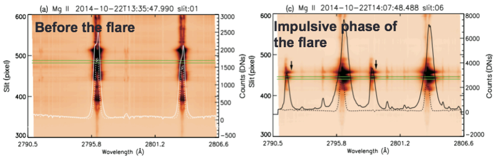
I.2 Energy transport process



- Need to check temporal evolution of the low atmospheric response with HXR emission

I.3 Low atmospheric heating signature

Mg II observation from IRIS



Mg II triplet become emission

(Pereira et al. 2015)

II. Observations

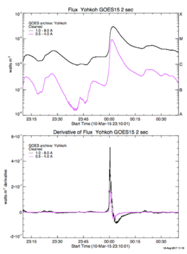
II.1 IRIS flare list

Table 1
List of flare (> M class) observed by IRIS with WLFs during 2014-2016

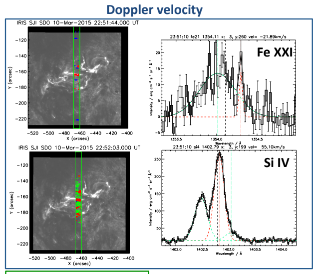
	GOES Flare Informaition					IRIS obs.								RHESSI obs.	
Number	Flare class	date	start (UT)	peak (UT)	end (UT)	obs mode	x1	y1	x2	y2	x3	y3	WLF	Obs. E range (keV)	HXR peak
1	M3.6	28-Jan-2014	07:25	07:31	07:34	scan	0	668					o	...	
2	M1.3	02-Feb-2014	21:24	22:04	22:14	scan	48	868						25-50	0.08
3	M1.5	04-Feb-2014	15:25	16:02	16:49	scan	15	330	5	205	41	162		25-50	0.5
4	M1.8	13-Feb-2014	01:32	01:40	01:50	scan	1	591	6	580	5	604		41997	0.04
5	X1.0	29-Mar-2014	17:35	17:48	17:54	scan	7	510	1	485	7	492	o	100-300	19.11
6	M7.3	18-Apr-2014	12:31	13:03	13:20	sns	0	648	0	650	0	629		50-100	0.56
7	M3.9	11-Jun-2014	20:53	21:03	21:10	scan	3	103	2	103	4	88		25-50	0.18
8	M1.0	12-Jun-2014	21:01	21:13	21:19	scan	2	51	5	102				41997	0.12
9	M1.5	01-Aug-2014	17:55	18:13	18:43	scan	40	453	20	381	11	238		...	
10	M1.1	06-Sep-2014	16:50	17:09	17:22	sns	0	258	0	314				50-100	0.86
11	X1.6	10-Sep-2014	17:21	17:45	18:20	sns	0	400	0	305	0	298		...	
12	M1.0	28-Sep-2014	16:34	17:33	18:00	scan	0	82	1	84	1	54		41997	0.05
13	M8.7	22-Oct-2014	01:16	01:59	02:28	sns	0	417	0	590			o	100-300	7.76
14	X1.6	22-Oct-2014	14:02	14:28	14:50	scan	6	443					o	100-300	16.39
15	X3.1	24-Oct-2014	21:07	21:41	22:13	sns	0	222	0	146	0	136	o[1]	100-300	9.31
16	X1.0	25-Oct-2014	16:55	17:08	18:11	sns	0	72	0	15				25-50	2.73
17	X2.0	26-Oct-2014	10:04	10:56	11:18	sns	0	181	0	253			o	...	
18	M1.0	26-Oct-2014	17:08	17:17	17:30	sns	0	102	0	218				...	
19	M2.4	26-Oct-2014	19:59	20:21	20:45	sns	0	67	0	133				...	
20	M7.1	27-Oct-2014	00:06	00:34	00:44	sns	0	90	0	159				25-50	0.46
21	M1.0	27-Oct-2014	01:44	02:02	02:11	sns	0	80	0	154				41997	0.06
22	M1.3	27-Oct-2014	03:35	03:41	03:48	sns	0	96	0	154				25-50	0.12
23	X2.0	27-Oct-2014	14:12	14:47	15:09	scan	0	63	1	342	6	127	o	50-100	2.98
24	M1.4	27-Oct-2014	17:33	17:40	17:47	scan	1	94	3	88				50-100	0.78
25	M3.4	28-Oct-2014	02:15	02:42	03:08	sns	0	118	0	282	0	192		...	
26	M6.6	28-Oct-2014	03:23	03:32	03:41	sns	0	284	0	305	0	326		25-50	0.59
27	M1.6	28-Oct-2014	13:54	14:06	14:23	scan	56	489	26	287	55	742		25-50	0.24
28	M1.0	29-Oct-2014	16:06	16:20	16:33	sns	0	147	0	160				...	
29	M1.0	07-Nov-2014	10:13	10:22	10:30	scan	7	230	7	272	10	228		25-50	0.08
30	X1.6	07-Nov-2014	16:53	17:26	17:34	scan	3	664	0	558			o[2]	...	
31	M2.3	09-Nov-2014	15:24	15:32	15:38	scan	2	326					o[2]	50-100	0.74
32	M5.6	13-Jan-2015	04:13	04:24	04:38	scan	4	22					o	...	
33	M5.8	09-Mar-2015	23:29	23:53	00:12	scan	4	346	4	326	4	336		...	
34	M2.9	10-Mar-2015	23:46	00:02	00:06	scan	3	240					o	100-300	11.12
35	M1.8	11-Mar-2015	07:10	07:18	07:43	scan	1	567	6	695	7	717		...	
36	M2.6	11-Mar-2015	07:51	07:57	08:03	scan	1	553	1	550	1	548		...	
37	X2.1	11-Mar-2015	16:11	16:22	16:29	scan	2	255	0	297	1	269	o	50-100	1.64
38	M1.6	12-Mar-2015	11:38	11:50	11:50	sns	0	287	0	243	0	188		...	
39	M1.4	12-Mar-2015	12:09	12:14	12:18	sns	0	200	0	290	0	240		...	
40	M1.8	13-Mar-2015	05:49	06:07	06:12	sns	0	282	0	241				50-100	0.18
41	M1.6	16-Mar-2015	10:39	10:58	11:17	scan	2	204	1	108	1	42		...	
42	M1.0	17-Mar-2015	22:49	23:34	23:48	scan	2	216						50-100	0.43
43	M6.5	22-Jun-2015	17:39	18:23	18:51	scan	6	216	14	80	2	79	o	50-100	1.76
44	M2.9	27-Aug-2015	04:48	05:44	06:03	scan	7	145	0	122				25-50	
45	M2.1	20-Sep-2015	17:32	18:03	18:29	sns	0	102	0	68				...	
46	M3.7	04-Nov-2015	13:31	13:52	14:13	scan	14	257	15	189	3	309		50-100	
47	M1.9	23-Jul-2016	01:46	02:11	02:23	scan	235	290	303	186				25-50	

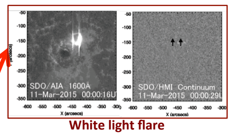
II.2 Sample event

- M 2.9 flare with WLF

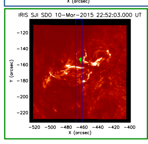


Doppler velocity





White light flare



Mg II triplet emission

- Fe XXI, Si IV doppler velocity variations are correlated with Mg II emission region in location and time

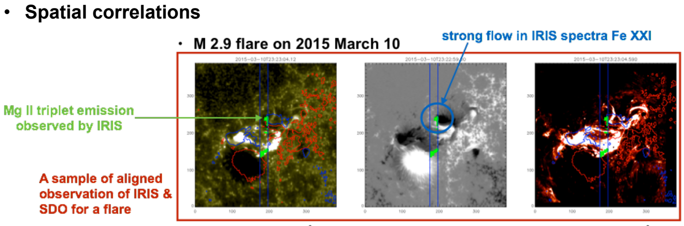
- **Mg II triplet emission**: If flare ribbon footpoints are detected to the IRIS slit, Mg II triplet emissions are observed.
- **WLFs (13/47, ~28%)**: Not all the events produce WLFs. If the HXR peak intensity value is less than 1, WLFs were not observed.

III. Results

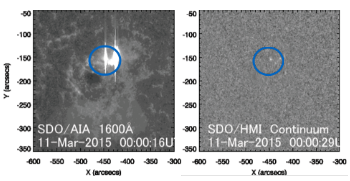
III.1 Correlations

- **Spatial correlations**

• **M 2.9 flare on 2015 March 10**



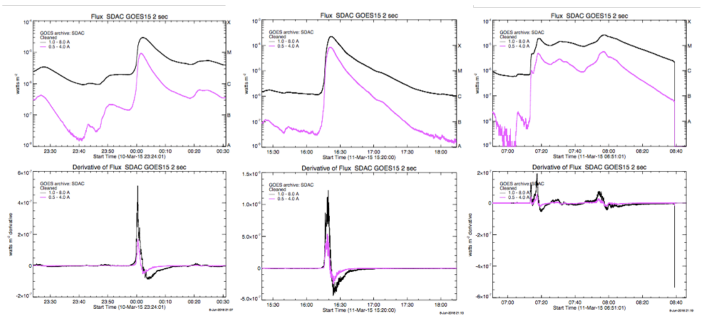
SDO/AIA 1600Å SDO/HMI LOS magnetogram IRIS/SJI 1330Å



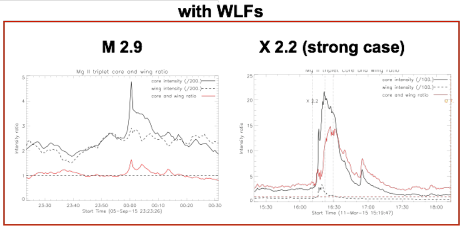
- Mg II triplet emission appears along flare ribbons
- Significant outflow (Doppler velocity) in Fe XXI observed at near the footpoints of flaring loop, not all the flare ribbon.
- WL flare kernel locations: combination of Mg II emitting region & Fe XXI outflowing region

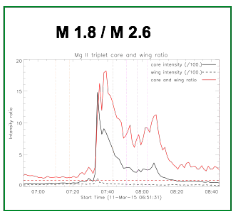
- **With WLFs:** Temporal correlations with HXR peaks and Mg II triplet emission peaks
  - **Strong flare cases** – continuum enhancement suppresses the ratio value
- **Without WLFs:** Mg II triplet emission peaks are observed after the HXR peaks or the SXR peaks

III.2 Three different types of events



with WLFs without WLF





Poster

4. Eruptions in the solar atmosphere

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