

A report  
on the observations acquired by  
amateurs during  
the F-CHROMA Observing Campaign  
'F-HUNTERS II' (14-23 July 2016)

September 17, 2016



# 1 Overview of the flare activity

In contrast to the previous campaign (F-HUNTERS I) which end up having only a few of the flare events, our Sun surprised us with a lot of activities during the F-HUNTERS II campaign. Throughout the entire duration of this campaign i.e 14 July - 23 July 2016, this campaign witnessed 45 flare events of intensity class  $\geq C$  while 5 of them have been of the intensity class M (see Table 1). To add a tale of fortune to the overview of the campaign, it is worth mentioning that just two weeks before the campaign, the solar disk has been deprived of the sunspots as shown in the figure ??.

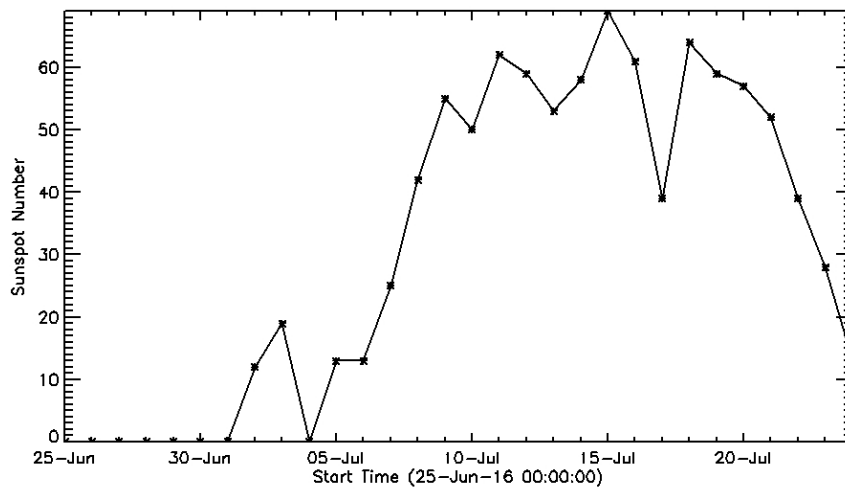


Figure 1: Sunspot number for the duration 25-June-2016 to 24-July-2016. Source: Sunspot Index and Long-term Solar Observations (SILSO) database

Table 1: Timeline and AR information of the Flare events of GOES intensity class  $\geq C$ , occurred during the campaign

Date	Start Time	Peak Time	End time	Class	AR Information
15-Jul-2016	15:07	15:11	15:14	C2.0	N05E35 12567
16-Jul-2016	00:28	00:34	00:38	C2.1	N05E30 12567
16-Jul-2016	01:13	01:19	01:23	C1.0	N05E29 12567
16-Jul-2016	02:07	02:16	02:20	C1.6	N05E28 12567
16-Jul-2016	02:46	02:50	02:52	C1.7	12567
16-Jul-2016	03:00	03:05	03:08	C1.5	N05E28 12567
16-Jul-2016	05:40	05:44	05:48	C2.0	12567
16-Jul-2016	05:57	06:00	06:03	C1.1	12567
16-Jul-2016	06:57	07:04	07:07	C6.8	12567
16-Jul-2016	08:17	08:23	08:27	C1.5	12567
16-Jul-2016	09:19	09:45	09:49	C1.0	12567
16-Jul-2016	10:26	10:33	10:38	C1.1	12567
17-Jul-2016	01:36	01:40	01:43	C1.3	N04E17 12567
17-Jul-2016	05:36	08:03	11:26	C1.4	N07E15 12565

17-Jul-2016	16:34	17:10	17:28	C1.0	N02E02 12565
17-Jul-2016	21:31	23:35	00:01	C6.6	12565
18-Jul-2016	08:09	08:23	08:32	C4.4	12565
19-Jul-2016	00:13	00:22	00:34	C1.0	N07W18 12565
19-Jul-2016	10:00	11:53	12:34	C2.2	N03W23 12565
20-Jul-2016	01:20	01:27	01:42	C1.3	N07W32 12567
20-Jul-2016	02:40	02:49	02:59	C1.6	N01W30 12567
20-Jul-2016	03:08	03:17	03:26	C4.2	N01W30 12567
20-Jul-2016	03:32	03:35	03:38	C2.5	N07W18 12565
20-Jul-2016	22:03	22:17	22:54	C4.6	12567
20-Jul-2016	23:30	23:35	23:39	C3.6	12567
20-Jul-2016	23:45	23:51	23:54	C3.4	12567
21-Jul-2016	00:19	00:37	00:41	C3.7	12567
21-Jul-2016	00:42	00:46	00:50	M1.2	12567
21-Jul-2016	01:34	01:49	02:04	M1.0	12567
21-Jul-2016	04:09	04:13	04:16	C1.6	
21-Jul-2016	09:40	09:44	09:48	C1.0	N00W47 12567
21-Jul-2016	11:06	11:19	11:22	C7.2	N00W48 12567
21-Jul-2016	12:47	12:55	13:03	C9.1	N01W49 12567
21-Jul-2016	13:30	13:34	13:37	C2.2	N03W50 12567
21-Jul-2016	15:38	15:42	15:47	C1.2	N03W51 12567
21-Jul-2016	17:00	17:04	17:16	C1.2	N05W53 12567
21-Jul-2016	22:34	22:46	22:58	C3.6	12567
22-Jul-2016	06:34	06:51	06:58	C6.6	N01W59 12567
22-Jul-2016	07:23	07:26	07:31	C1.2	N00W61 12567
22-Jul-2016	20:09	20:20	20:31	C2.4	N07W68 12567
23-Jul-2016	01:46	02:11	02:23	M5.0	12567
23-Jul-2016	03:38	03:42	03:45	C1.4	12567
23-Jul-2016	05:00	05:16	05:24	M7.6	12567
23-Jul-2016	05:27	05:31	05:33	M5.5	N02W74 12567
23-Jul-2016	09:04	09:11	09:16	C1.0	12567
23-Jul-2016	10:20	10:32	10:35	C1.1	12567
23-Jul-2016	12:48	12:57	13:05	C1.8	N06W77 12567
23-Jul-2016	17:38	17:55	18:04	C2.4	12567
23-Jul-2016	23:30	23:36	23:45	C1.3	12567

## 2 Observations obtained by amateur observers during *F-CHROMA Observing Campaign*

Although the clouds have succeeded in their purpose by destroying the chances of observing the Sun for some duration in the beginning of the campaign, solar atmosphere in optical wavelength band has been captured by a large number of amateur observers ( $\sim 150$ ; number based on the subscribers of the F-HUNTERS II campaign newsletter) from all around the world. At the end of the campaign, we received ample amount of data containing the solar images in various optical wavelengths including in  $H\alpha$  line center, off-band and in visible from around twenty amateurs. As mentioned in the previous section, this campaign has witnessed a lot of flare activity, a day-wise report of the observations, gathered

by the amateurs during the campaign, is presented as following.

## 2.1 July 14, 2016

Uninterrupted disk-integrated observations in X-ray waveband, provided by GOES satellite revealed that flare activity on the Sun on this day was very poor, with no flare events of GOES intensity class C or higher. Figure 2 presents the evolution of X-ray emission in 1-8 Å, as obtained by *GOES*, in black color. Many amateur observers reportedly recorded the target region, selected and distributed by the F-HUNTERS II coordination team. Left panel of the Figure 2 shows the distributed target information while the right panel presents a brief schematics of the observing duration and wavelength etc. is shown in Figure 2. The two dotted lines corresponding to a certain color show the time duration of data obtained by the respective observer, while the respective names are annotated in the legends with the same color.

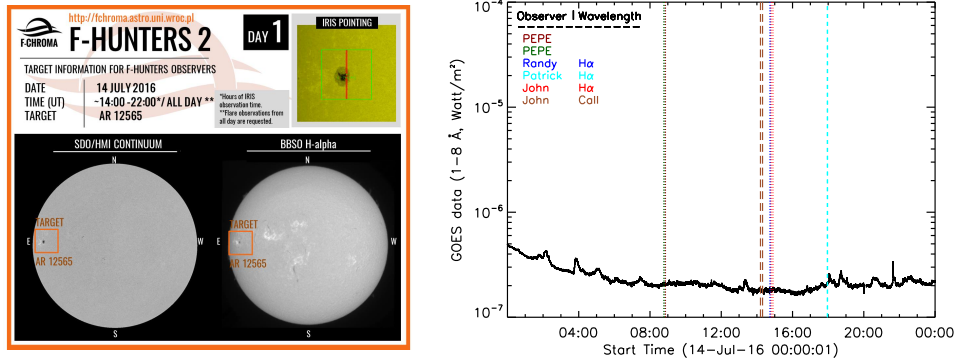


Figure 2: *Left Panel:* Target information distributed to the amateur observers. *Right Panel:* GOES observations in 1-8 Å are shown in black colour. Time duration, and type of record obtained several amateurs co-temporal to the *GOES* observations are shown by dotted lines in various colors.

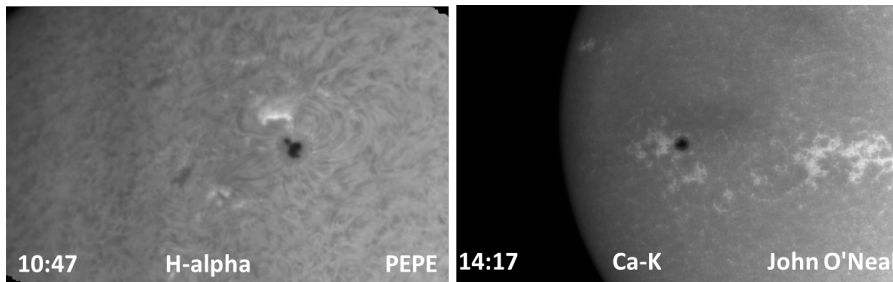


Figure 3: H $\alpha$  and Ca-K images of the Sun obtained on 14-Jul-2016. The time, wavelength and observer's name is annotated in respective images.

It may be noted that although several records have been obtained in multi-wavelength bands, however, no flares have been captured. Presented in figure 3 is the observations of the active region obtained on this day by two of the observers.

## 2.2 July 15, 2016

On July 15, 2016, a C2.0 flare occurred on the Sun in AR12567. Left panel of the Figure 4 shows the distributed target information while the right panel presents *GOES* observations in 1-8 Å, shown in black colour. Similar to the previous section, we overplot the records obtained by various amateur observers in different colors.

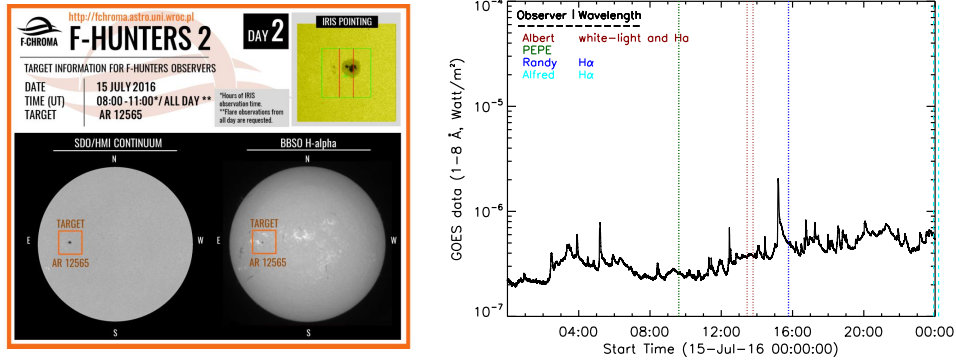


Figure 4: *Left Panel:* Target information distributed to the amateur observers. *Right Panel:* *GOES* observations in 1-8 Å are shown in black colour. Time duration, and type of record obtained several amateurs co-temporal to the *GOES* observations are shown by dotted lines in various colors.

Although several records have been obtained by amateurs in multi-wavelength bands, however, no activity has been substantially captured. Presented in figure 5 is a time sequence of the images of the target AR in white light obtained by one of the observers.

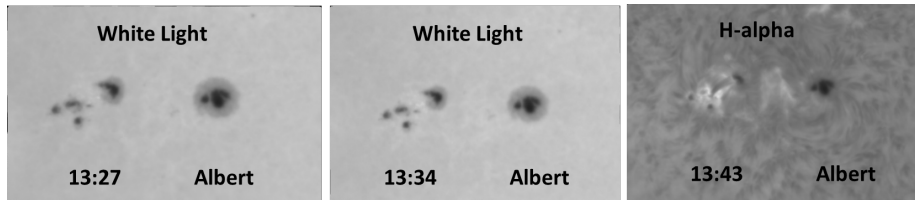


Figure 5: Time sequence of white-light images of the Sun obtained on 15-Jul-2016. The time, wavelength and observer's name is annotated in respective images.

### 2.3 July 16, 2016

On July 16, 2016, the Sun was very active and produced 11 C-class flare, however, before the announced campaign coordinated observation time. Left panel of the Figure 6 shows the distributed target information while the right panel shows *GOES* observations in 1-8 Å as shown in black colour. Observations from enthusiast amateurs has been obtained and annotated in the figure 6 as well.

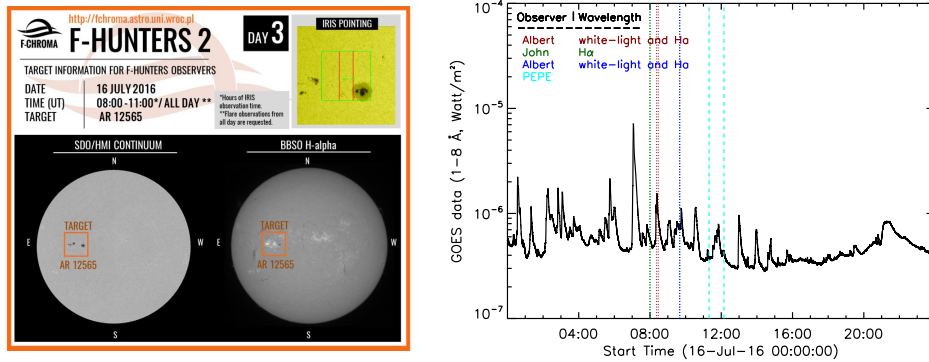


Figure 6: *Left Panel:* Target information distributed to the amateur observers. *Right Panel:* *GOES* observations in 1-8 Å are shown in black colour. Time duration, and type of record obtained several amateurs co-temporal to the *GOES* observations are shown by dotted lines in various colors.

We learn that several records in the H $\alpha$  and white light wavelengths have been obtained by the amateurs. Although the records correspond to a small flaring activities, in figure 7, we present some of the interesting observations recorded by the observers.

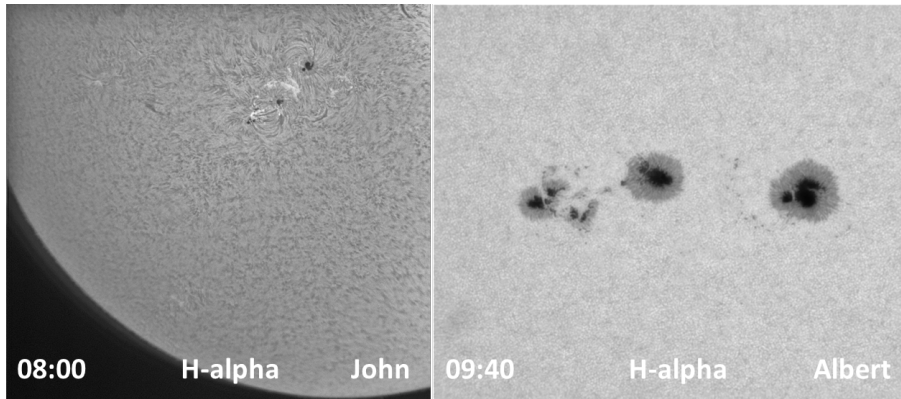


Figure 7: H $\alpha$  and white-light images of the Sun obtained on 16-Jul-2016. The time, wavelength and observer's name is annotated in respective images.

## 2.4 July 17, 2016

Although several observations in multi-wavelength band have been recorded by many amateur observers on July 17, 2016, the X-ray activity on this day happened to be beyond the coordinated observing time. A total of 4 C-class flares occurred as seen from *GOES* X-ray observations. Left panel of the Figure 8 shows the distributed target information while the right panel shows the coverage of data obtained from the amateurs, shown in respective colours. *GOES* observations in 1-8 Å are shown in black colour.

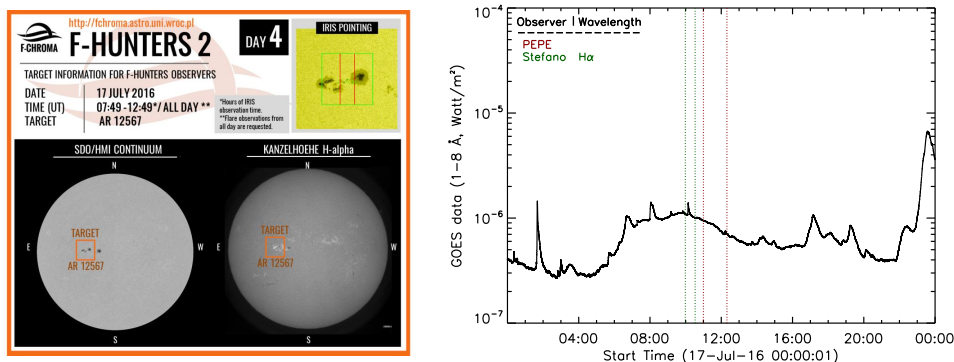


Figure 8: *Left Panel:* Target information distributed to the amateur observers. *Right Panel:* *GOES* observations in 1-8 Å are shown in black colour. Time duration, and type of record obtained several amateurs co-temporal to the *GOES* observations are shown by dotted lines in various colors.

It is to be noted that during the early decay phase of a long-duration small intensity class flare which occurred in the AR12567, an observer Stefano, recorded the time sequence of images in H $\alpha$  wavelength using Mount Gemini G42, refractor D. mm 152 f/25, filter FWHM 0.7Å. A sequence of images is presented in figure 9 for brief overview.

## 2.5 July 18, 2016

Several observations in multi-wavelength band have been recorded by many amateur observers on July 18, 2016. On the other hand, the flaring activity on this day was moderate resulting in only one C4.4 flare. Left panel of the Figure 10 shows the distributed target information while the right panel shows the coverage of data obtained from the amateurs, shown in respective colours. *GOES* observations in 1-8 Å are shown in black colour.

We note that during the decay phase of the c4.4 flare which occurred in the AR12565, an observer Herald, recorded the time sequence of images in H $\alpha$  wavelength during 10:33 UT - 11:54 UT using triple stack etalons, stack 65/330frames fps 30. A sequence of representative images are shown in figure 11 for brief overview.

Similarly, other noticeable observations were taken by an observer Pepe who recorded fast-cadence images in H $\alpha$  wavelength during 10:15 - 10:25 UT, cov-

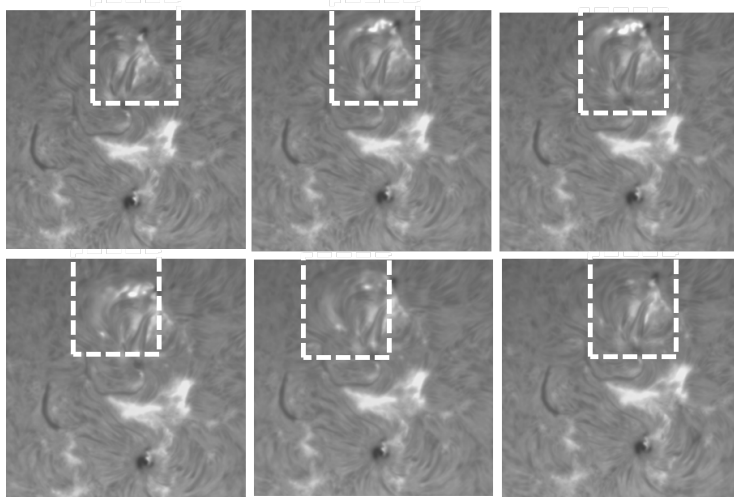


Figure 9: Time sequence of  $H\alpha$  images of the Sun obtained on 17-Jul-2016 during 09:59 - 10:32 UT. Ongoing flaring activity and mass motion may be clearly noted within the box.

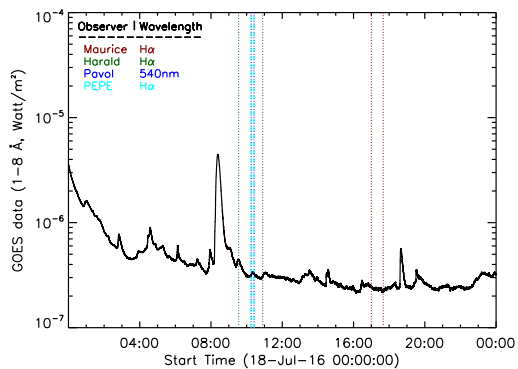
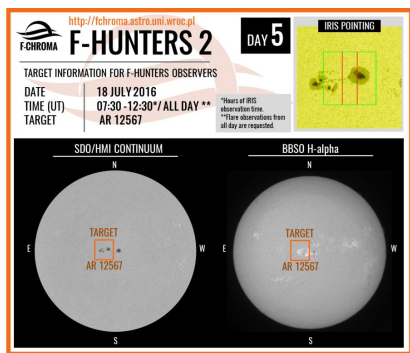


Figure 10: *Left Panel:* Target information distributed to the amateur observers. *Right Panel:* GOES observations in 1-8 Å are shown in black colour. Time duration, and type of record obtained several amateurs co-temporal to the GOES observations are shown by dotted lines in various colors.



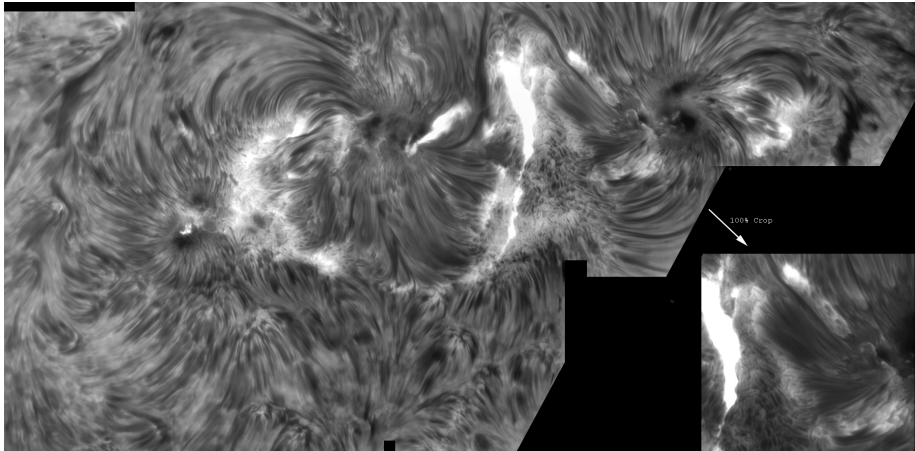


Figure 11: A processed image in  $H\alpha$  wavelength, as provided by the observer Herald. The image corresponds to the maximum phase of the C4.4 flare.

ering the gradual phase of the C4.4 flare. A sequence of representative images, recorded by him, are presented in figure 12 for brief overview.

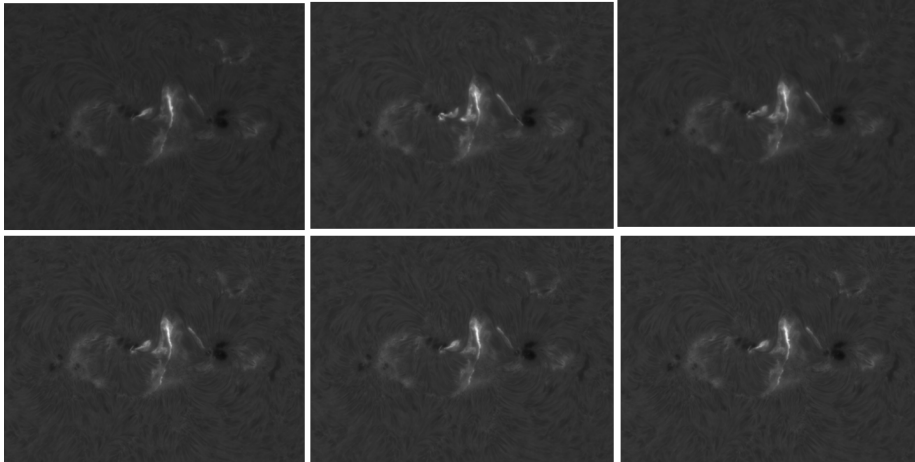


Figure 12: Time sequence of  $H\alpha$  images of AR 12565 during the early gradual phase of the C4.4 flare.

From the figure 12, time evolution of  $H\alpha$  brightening between the opposite polarities may easily be noted. Although these images are captured in fast-cadence the overall coverage of the record is very small which makes this time-sequence alone insufficient for temporal and spatial analysis. For better visualization, a movie of all the images from the said observer may be retrieved from the link: [http://www.astro.uni.wroc.pl/ludzie/awasthi/fchroma-public/18\\_07\\_2016.mp4](http://www.astro.uni.wroc.pl/ludzie/awasthi/fchroma-public/18_07_2016.mp4)

## 2.6 July 19, 2016

Solar flare activity on July 19, 2016 was moderate with only two C-class flares. Several observations in multi-wavelength band have been recorded by many amateur observers. Left panel of the Figure 13 shows the distributed target information while the right panel shows the coverage of data obtained from the amateurs, shown in respective colours. *GOES* observations in 1-8 Å are shown in black colour.

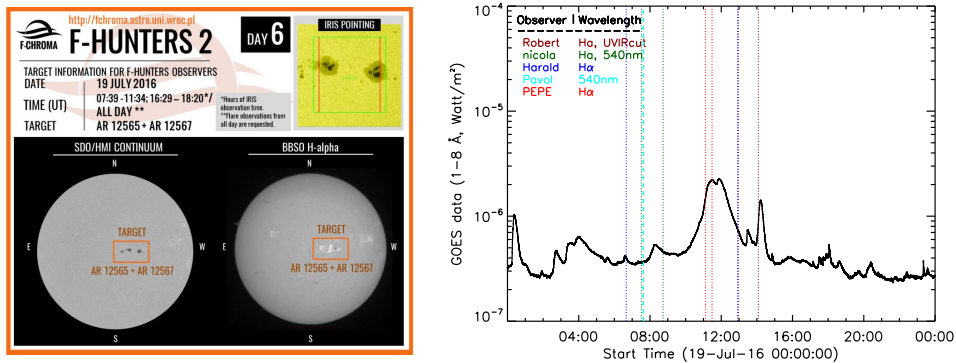


Figure 13: *Left Panel:* Target information distributed to the amateur observers. *Right Panel:* *GOES* observations in 1-8 Å are shown in black colour. Time duration, and type of record obtained several amateurs co-temporal to the *GOES* observations are shown by dotted lines in various colors.

We note that during 11:07 - 11:29 UT, covering the rise to maximum phase of the C2.2 flare which occurred in the AR12565, an observer, Pepe, recorded the time sequence of images in H $\alpha$  wavelength. A sequence of representative images are shown in figure 14 for brief overview.

## 2.7 July 20, 2016

Although solar flare activity on July 20, 2016 was higher with seven C-class flares during the day, none occurred during the coordinated observing campaign time. Irrespective of this fact, several observations in multi-wavelength band have been recorded by many amateur observers. Left panel of the Figure 15 shows the distributed target information while the right panel shows the coverage of data obtained from the amateurs, shown in respective colours. *GOES* observations in 1-8 Å are shown in black colour.

After having an overview of all the observations recorded during this day, we find the image sequence of an observer Herald to be most interesting and also covering many minor flaring activities. A sequence of representative images are shown in figure 16 for brief overview.

Moreover, as several activities are also covered in the observations taken by an observer Pepe, a movie of the image sequence is put on the URL [http://www.astro.uni.wroc.pl/ludzie/awasthi/fchroma-public/20\\_07\\_2016.mp4](http://www.astro.uni.wroc.pl/ludzie/awasthi/fchroma-public/20_07_2016.mp4)

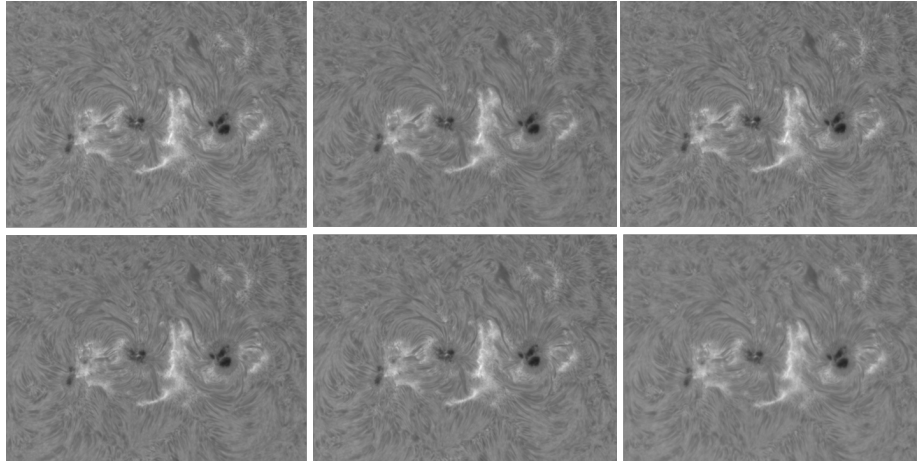


Figure 14: Time sequence of the  $H\alpha$  images of AR12565. The images corresponds to the rise to the maximum phase of the C2.2 flare.

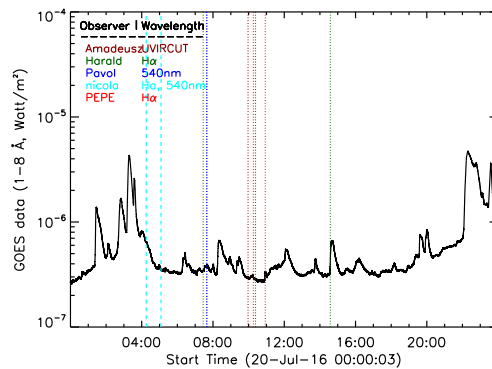
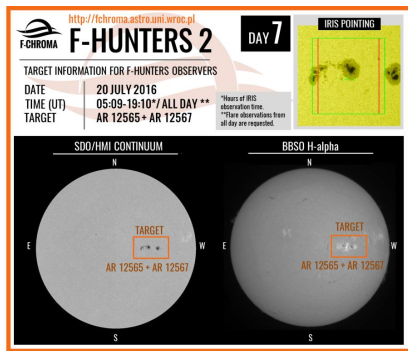


Figure 15: *Left Panel:* Target information distributed to the amateur observers. *Right Panel:* GOES observations in 1-8 Å are shown in black colour. Time duration, and type of record obtained several amateurs co-temporal to the *GOES* observations are shown by dotted lines in various colours.

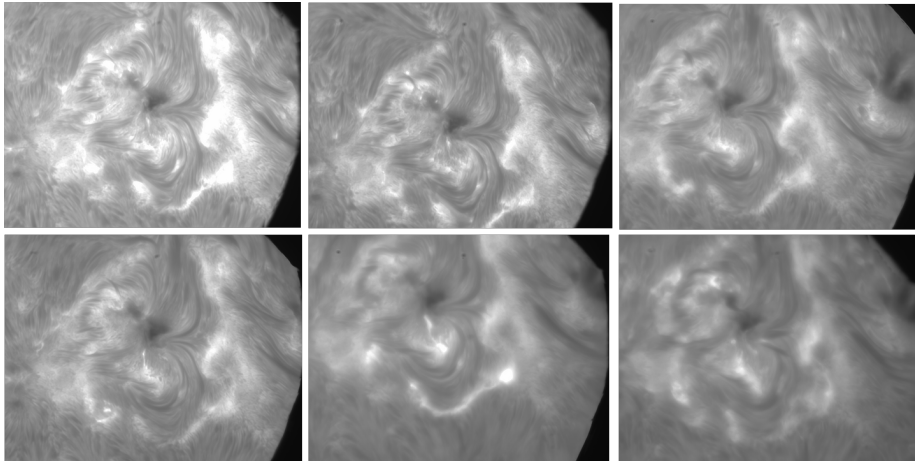


Figure 16: Time sequence of the  $H\alpha$  images of AR12567. The images corresponds to the minor flaring activities during 07:27 UT to 14:35 UT.

## 2.8 July 21, 2016

The Sun was very active on July 22, 2016 with 9 C-class and 2 M-class flares during the day. During the coordinated observing campaign time, several observations in multi-wavelength band have been recorded by many amateur observers. Left panel of the Figure 17 shows the distributed target information while the right panel shows the coverage of data obtained from the amateurs, shown in respective colours. *GOES* observations in 1-8 Å are shown in black colour.

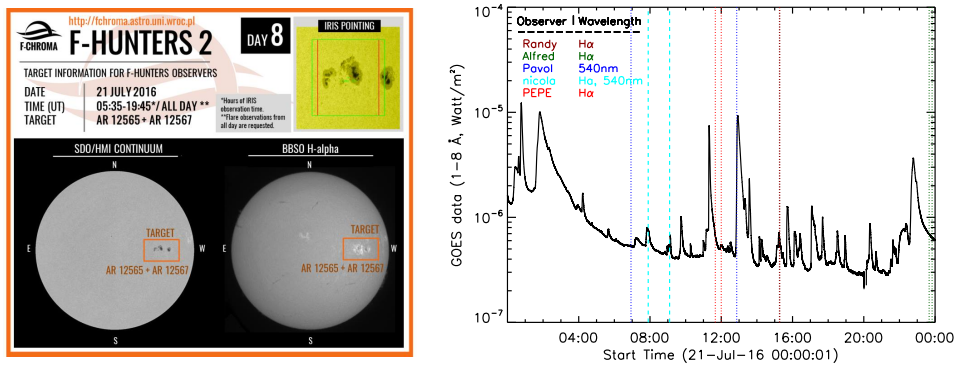


Figure 17: *Left Panel:* Target information distributed to the amateur observers. *Right Panel:* GOES observations in 1-8 Å are shown in black colour. Time duration, and type of record obtained several amateurs co-temporal to the *GOES* observations are shown by dotted lines in various colors.

An overview of all the observations recorded during this day revealed that

Pepe recorded the gradual phase of C9.1 flare which occurred in the AR12567. Time sequence of the images are shown in figure 18.

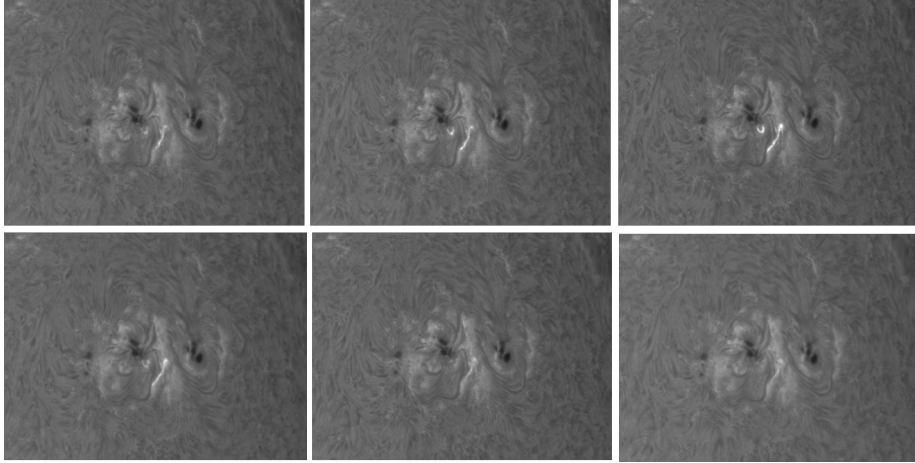


Figure 18: Time sequence of the  $H\alpha$  images of AR12567. The images corresponds to the minor flaring activities during 11:40 UT to 12:00 UT.

The images shown in figure 18 reveal high activity of the solar chromosphere in the decay phase of the flare. Although the time-span of the observation, provided by the observer is not very high, the temporal cadence and quality of the images make it worth for further analysis. Also, a movie of the image sequence, recorded by Pepe is put on the URL [http://www.astro.uni.wroc.pl/ludzie/awasthi/fchroma-public/21\\_07\\_2016.mp4](http://www.astro.uni.wroc.pl/ludzie/awasthi/fchroma-public/21_07_2016.mp4)

## 2.9 July 22, 2016

In comparison to the previous days, the flare activity on the Sun was moderate on July 22, 2016 with only 3 C-class flares during the whole day. Several observations in multi-wavelength band have been recorded by many amateur observers covering various phases of the flare. Left panel of the Figure 19 shows the distributed target information while the right panel shows the coverage of data obtained from the amateurs, shown in respective colours. *GOES* observations in 1-8 Å are shown in black colour.

Special mention is due to the observer Herald who recorded maximum to the decay phase of C6.6 flare which occurred in the AR12567. Time sequence of the images are shown in figure 20.

The images shown in figure 20 reveal high activity of the solar chromosphere in the maximum and the decay phase of the flare. Moreover, the flare coverage has also been good which require further detailed analysis in conjunction with other wavelengths.

## 2.10 July 23, 2016

At the last day of the campaign i.e. on July 23, 2016, the flare activity on the Sun was at its best with 3 M-class flares and 6 C-class flares during the whole day.

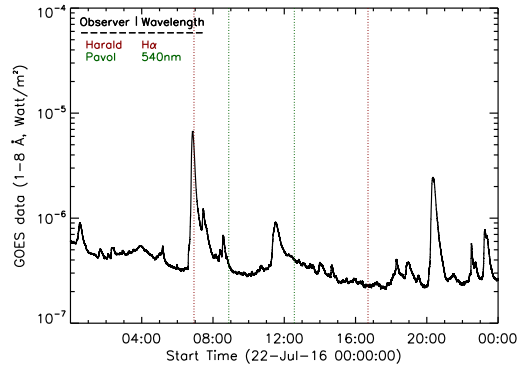
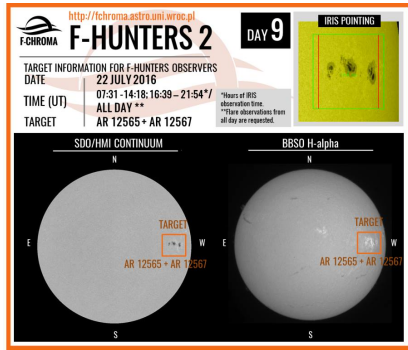


Figure 19: *Left Panel:* Target information distributed to the amateur observers. *Right Panel:* GOES observations in 1-8 Å are shown in black colour. Time duration, and type of record obtained several amateurs co-temporal to the *GOES* observations are shown by dotted lines in various colors.

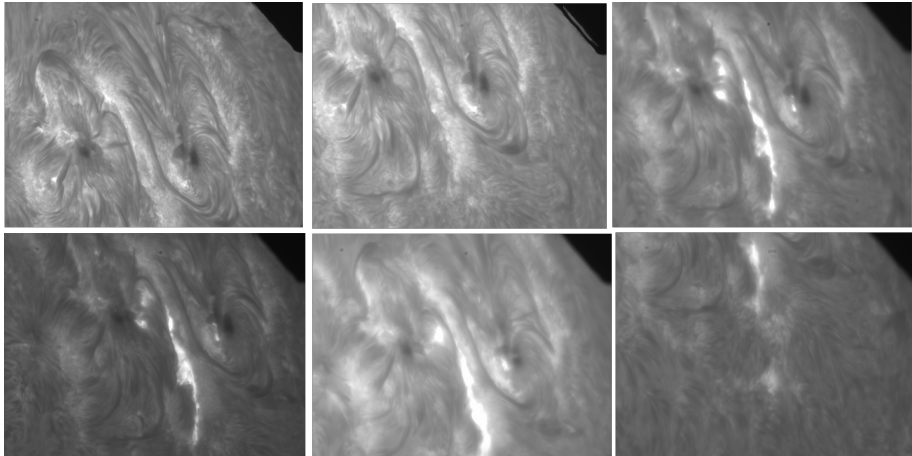


Figure 20: Time sequence of the H $\alpha$  images of AR12567. The images corresponds to the minor flaring activities during 06:56 UT to 16:42 UT.

Several observations in  $H\alpha$  wavelength has been recorded by two of the observers covering various phases of the flare. Left panel of the Figure 21 shows the distributed target information while the right panel shows the coverage of data obtained from the amateurs, shown in respective colours. *GOES* observations in 1-8 Å are shown in black colour.

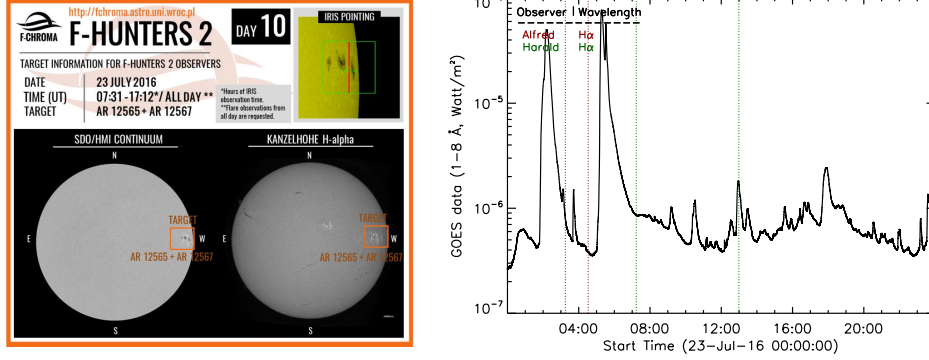


Figure 21: *Left Panel:* Target information distributed to the amateur observers. *Right Panel:* *GOES* observations in 1-8 Å are shown in black colour. Time duration, and type of record obtained several amateurs co-temporal to the *GOES* observations are shown by dotted lines in various colors.

An overview of the observations recorded during the whole day revealed that several interesting features have been recorded. Observer Alfred observed the decay phase of M5.0 flare in  $H\alpha$  wavelength. Moreover, Herald has also provided us with wonderful images of the Sun in  $H\alpha$  during 07:14 - 12:59 UT, covering several chromospheric activities during the whole day. Time sequence of the images, obtained by Alfred are shown in figure 22.

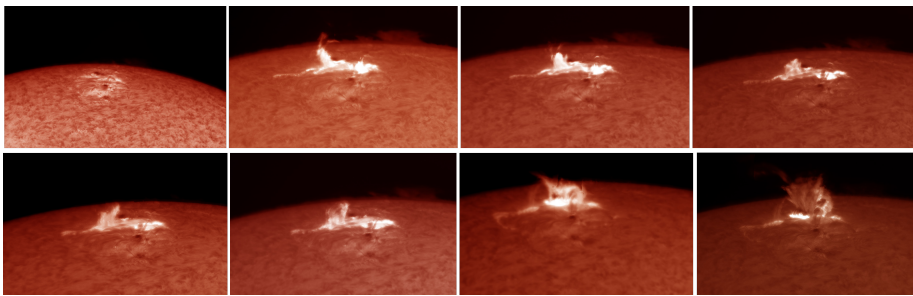


Figure 22: Time sequence of the  $H\alpha$  images of AR12567 during M5.0 flare as recorded by observer Alfred. The images corresponds to the post-impulsive phase flaring activities during 04:15 UT - 05:32 UT.

The images shown in figure 22 reveal high activity of the solar chromosphere in the maximum and the decay phase of the flare. Although the cadence of the images is poor, the quality of the images are very good. Detailed analysis of the

event with aforementioned images is therefore recommended. Next, we present the representative sequence of images acquired by another observer Herald. He recorded the activities of the solar chromosphere in  $H\alpha$  wavelength during the decay phase of M7.6 class flare and beyond. Time sequence of a few representative images, obtained by Herald covering the duration 07:14 - 12:59 UT, is shown in figure 23.

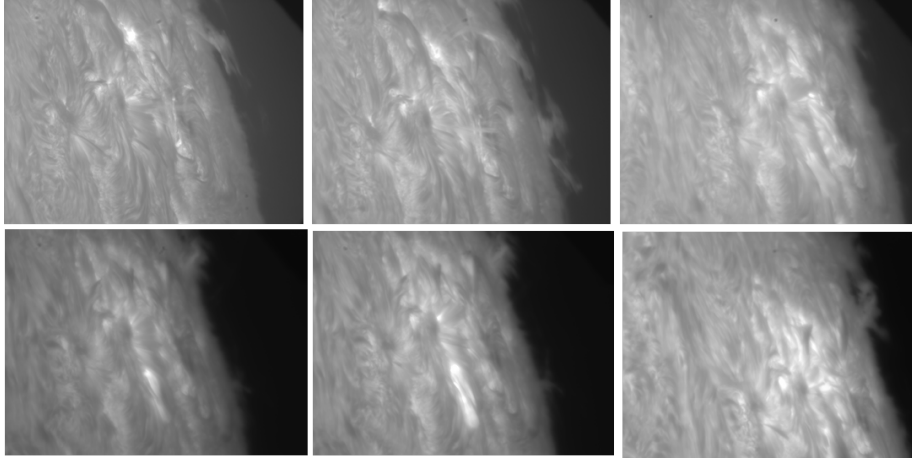


Figure 23: Time sequence of the  $H\alpha$  images of AR12567 during the decay phase of M7.6 flare as recorded by observer Herald. The images corresponds to the post-impulsive phase flaring activities during 07:14 - 12:59 UT.

### 3 Summary

As presented in the previous section, an exhaustive overview of the data acquired by amateur observers in co-ordination with the F-CHROMA observing campaign is given. A special appeal, which was made just before the campaign in view of acquiring long-time series of the observations was successful as a few of the observers acquired as well as provided several images recorded during long time span. This stamps the success of outreach efforts made by F-CHROMA outreach team in view of the second F-HUNTERS campaign. *It is to be noted that a few of the observations acquired by the amateurs possess potential of utilizing the same for detailed scientific analysis.* Moreover, the observations obtained during the campaign mostly covered  $H\alpha$  and white-light Sun, and hence, serve the purpose of providing a qualitative insight of the active region during its quiet and eruptive phase.