Simultaneous observation of a hot explosion by NST and IRIS

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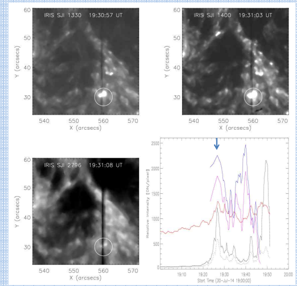
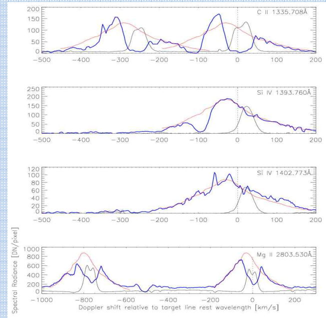
We present the first simultaneous observation of the so-called hot explosion in the cool atmosphere of the Sun made by New Solar Telescope (NST) of Big Bear Solar Observatory (BBSO) and Interface Region Imaging Spectrograph (IRIS) in space. The data obtained during the joint IRIS-NST observation on 2014 July 30. The explosion of interest started around 19:20 UT and lasted for about 10 minutes. The IRIS brightening was observed in 3 channels of slit-jaw images and the Si IV emission profile showed the highly blue-shifted (-30 km/s) single-gaussian type. Wing brightening with a related surges were observed in both bands of the NST Fast Imaging Solar Spectrograph (FISS) instrument. The elongated granule seen in NST TiO data contributed to the emergence of positive flux to trigger the hot explosion. These observations suggest that an inclined IRIS hot explosion occurred in the cool atmosphere of the Sun can simultaneously observed as an Ellerman bomb (EB) in Hα wing.

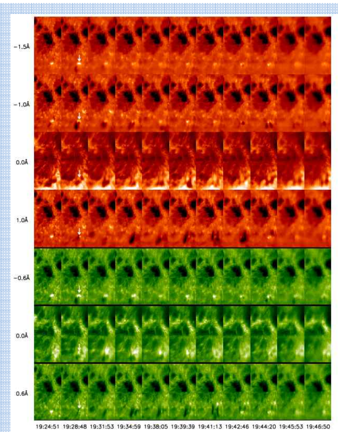


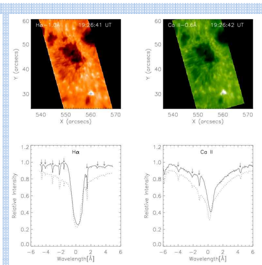
The IRIS brightening was observed in 3 channels of slit-jaw images, which covers temperature range from 4,000 to 80,000 K. The brightening occurred in the lower right corner (560", 30") of the field of view.



First of all we find that during the brightening the intensities of all spectral lines are strongly enhanced. The Si IV profiles are the single-Gaussian type with strong blue shifts of about -30 km/s. It should be noted that the similarity of the profiles of C II, Si IV, and Mg II is remarkable. It is natural to assume that material ejected from the brightening have temperatures from 6,000 to 100,000 K and must be a multi-thermal plasma. The profile features of our event are very similar to those of the 'bomb 3' event reported by Peter at al. (2014), except the weak spectral radiances of C II and Si IV lines.

The above figure shows IRIS intensity profiles of the brightening that peaked at 19:26:53 UT. The thin solid line is the averaged spectrum and the averaging was performed over the limited spatial and temporal ranges. It should be noted that we could not obtain the average profiles over the quiet region due to the IRIS observing mode (sit-and-stare) and they do not present the quiet sun information.





The wing enhancement is not very strong and does not extend to the far wings (< 5 Å). This means that the brightening occurred at the relatively higher levels of the atmosphere and did not reach deep down to the lower atmosphere of the Sun. Based on these spectral characteristics, we conclude that this event is an EB having a relatively weak intensity and associated surges.

Figure shows time series of FISS raster scans that show atmospheric levels in the blue wing, line center, and the red wing of the Hα 6562.8 Å and Ca II 8542 Å spectral lines. We found several wing brightenings accompanied by eruptions of dense chromospheric material. There are no associated emission signatures in the Hα line center. Temporal evolution of the brightening seems to be to be well associated and co-temporal in both bands. Surge had a projected speed of ~26 km/s.

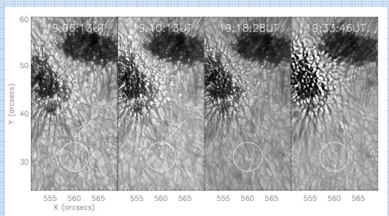
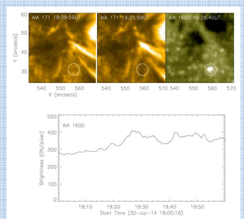
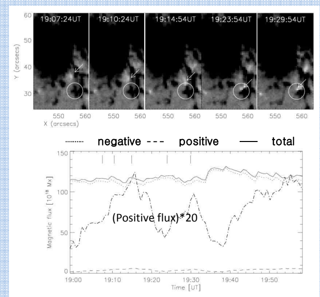


Figure shows TiO broadband images. At 19:06:13 UT, a remarkable elongated structure appeared at the edge of a small sunspot of following polarity in NOAA AR 12121. This structure continuously stretched out and moved toward the brightening site. Similar event was studied by Lim et al. (2012) who concluded that these photospheric flows were associated with flux emergence.

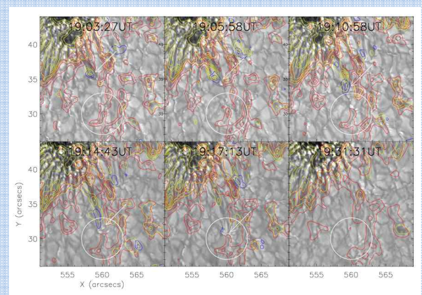
We also analyzed vertical motions of plasma. We were able to identify red-shifted signals (~1 km/s) in the HMI dopplergram related to the brightening. The Doppler upflow velocity of EB is estimated to be around 11 km/s.



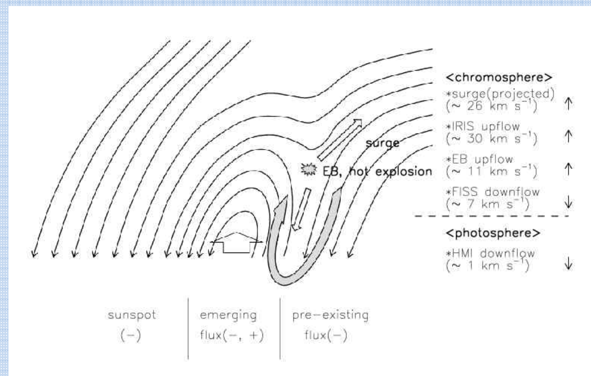
In AIA 1600 Å channel, light curve is well consistent with the IRIS brightening. In AIA 171 Å channel, we found that dark material appeared around the brightening time. . AIA 304 Å channel showed no remarkable features regarding this brightening.



The major polarity of the brightening site is negative and a part of positive flux transferred from main sunspot to the brightening site. Although the positive flux contributed only a small portion to the total flux, it showed highly dynamic evolution and seemed to play an important role in triggering the brightening. Around the peak time of the IRIS brightening, there is no significant changes in the longitudinal magnetic field. It means that the IRIS brightening may be due to magnetic reconnection between the emerging flux (+) and existing flux (-) in the higher atmosphere, and not due to reconnection of U-shaped field lines that supposedly occurs in the photosphere.



One of the footpoints of the stretched granule in TiO image (white arrows) was co-spatial with the positive flux patch (blue contour) while the transverse flux (yellow contour) was co-spatial with the spine of the stretched structure. This indicates a new emerging flux tube.



The velocity pattern of the event showed a series of downflows and upflows related to the hot explosion: HMI downflows of about 1 km/s (about 150 km, photospheric height), FISS downflows with a speed of about 7 km/s (chromospheric height), Ellerman bomb (EB) upflows of about 11 km/s (maybe chromospheric height), Si IV upflows of about 30 km/s (transition region temperature, but maybe chromospheric height), and surge eruption with a projection speed of about 26 km/s (upper chromosphere or higher). Based on our results, we suggest the magnetic field configuration for our event (the above figure). In the figure, the hot explosion and EB can occur simultaneously by magnetic reconnection between newly emerging flux and pre-existing negative flux in the middle or upper chromosphere. Watanabe et al. (2008) studied the association between EB and emerging flux tubes and discussed three triggering mechanisms for EBs. Our event seems to follow their model 1, i.e., magnetic reconnection occurs at the footpoint of the emerging flux tube.