A systematic study of HXR flares and Metric type III radio bursts between 2002 and 2015

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An Important Problem

Large scale particle acceleration happens in solar flares. X-ray and associated type III emission are the two most direct quantitative signature of accelerated electrons following an energy release event. What are the correlations that exist between these two populations of electrons? Were they originally part of the same source population of electrons? Does energy information contained in the HXR electrons correlate with the flux of the associated type III?

Methodology

We conducted an extensive survey spanning 2002-2014 to select events with temporally and spatially correlated HXR and type III radio emission. For HXR data we used RHESSI and FERMI. RHESSI data is available from 2002 till 2018, while FERMI data is available from 2008. FERMI data increases the chance to observe more HXR events that may have occurred during RHESSI night or SAA. We use a combination of instruments to track the radio emission of the type III. For frequencies above 100 MHz we use the PHOENIX spectrometer which is part of the e-CALLISTO network for events that occurred between 2002-2011 and the ORFEE spectrograph for events between 2012-2014. For frequencies between 10 and 100 MHz we used the Nancay Decametric Array(NDA). For frequencies below 10 MHz we used WIND/WAVES. Following criterion were required to be satisfied for an event to be included in the shortlist.

- For the flare we require good HXR counts above background at-least till 25 keV. A Well-defined and detectable rise and decay profile was also required. Events which were partially occulted while the instrument was in Earth's shadow were not included.
- A type III burst which had a clear presence in greater than 100 MHz frequency range. We also required that the event extend into the NDA. Presence of the burst in the WIND/WAVES instrument which indicated the interplanetary extension of the burst was not a pre-requisite. We further required that the type III fell within the rise or decay profile of the HXR flare.
- Clear increase of flux in the NRH 150 MHz frequency channel at the time of type III burst indicating that the event had a good representation in the NRH for flux measurements.

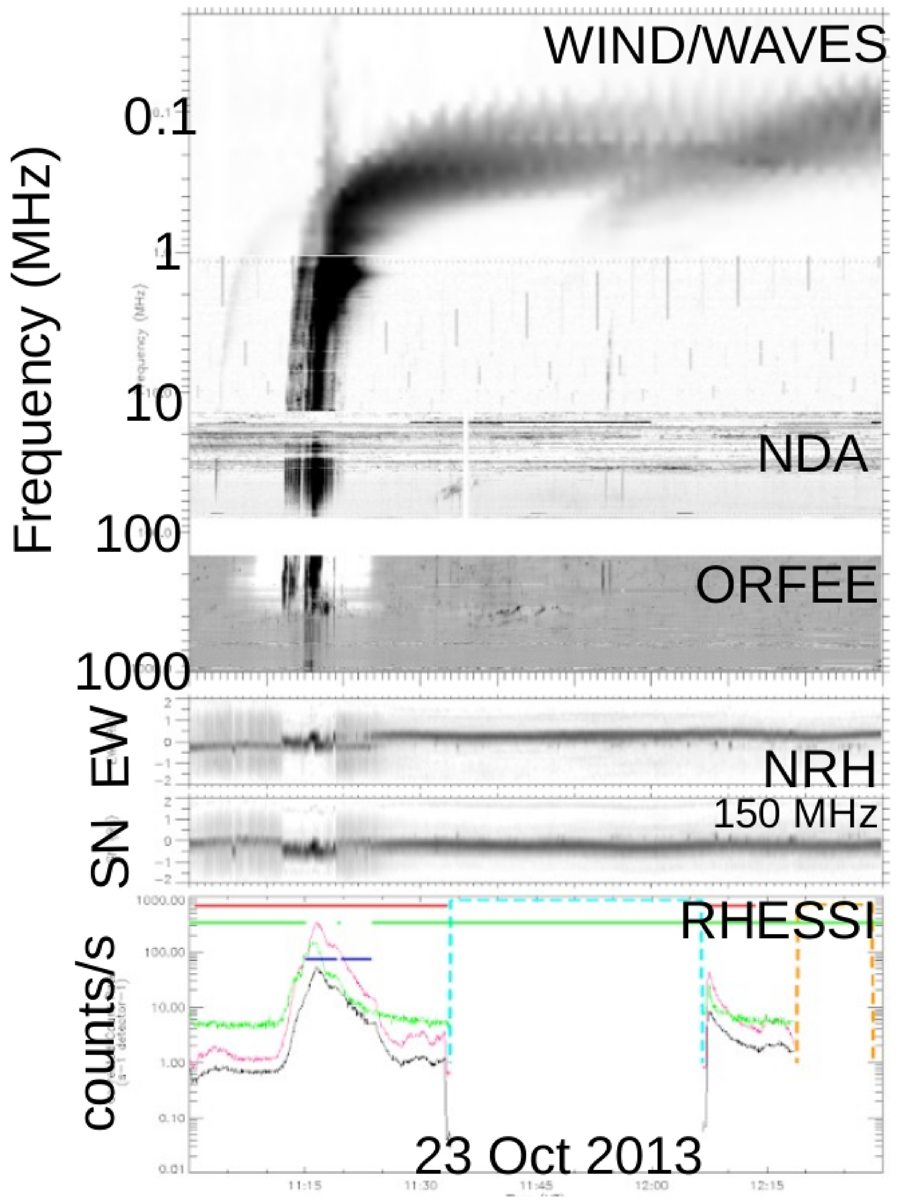

Fig. 1: The timeline of event the occurred on 11:15 UT 23 Oct 2013. A strong HXR flare recorded by RHESSI and the associated type III burst starting from ≈ 1000 MHz and then extending all the way across the sub MHz regime is seen.

Correlations

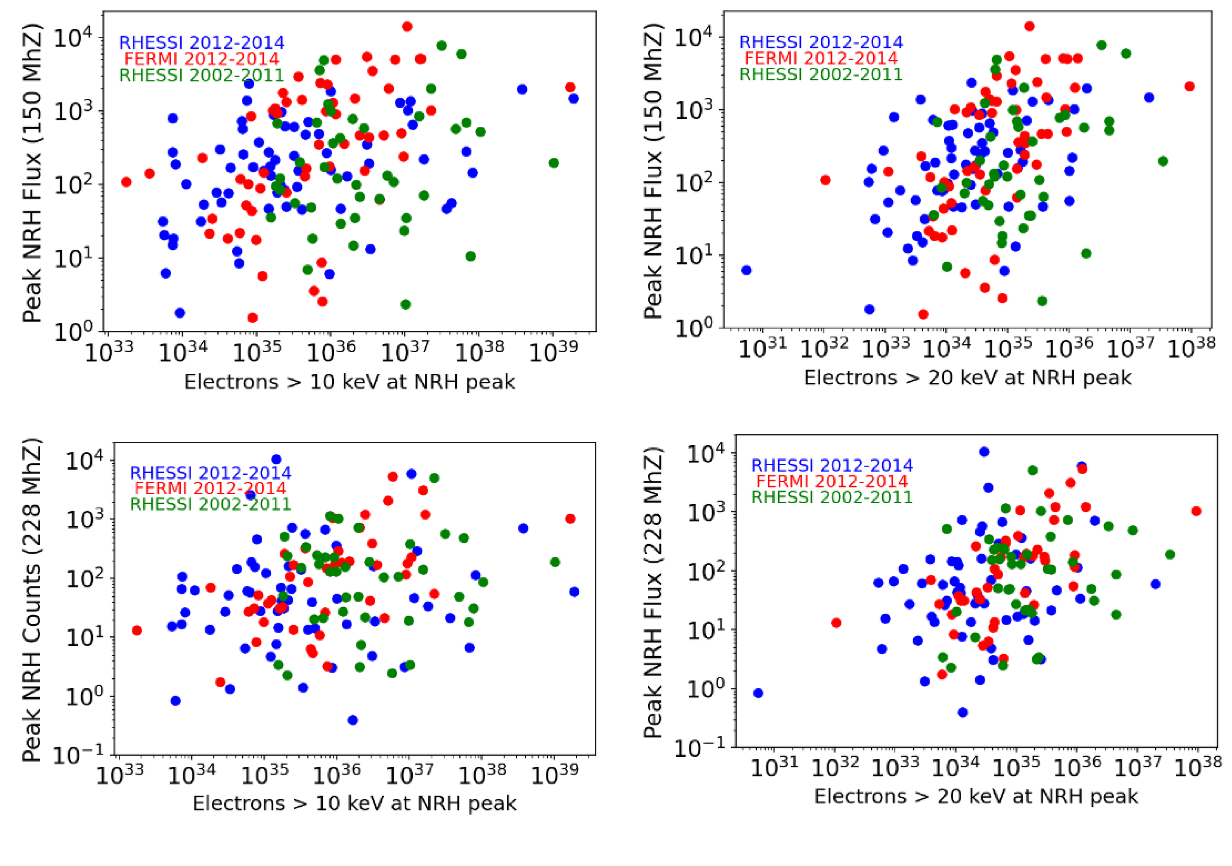

Fig. 2: Correlation plots between the number of electrons above 10 keV and 20 keV vs the peak NRH flux at different frequencies. The Spearman correlation coefficient between the two quantities is calculated using bootstrap sampling.

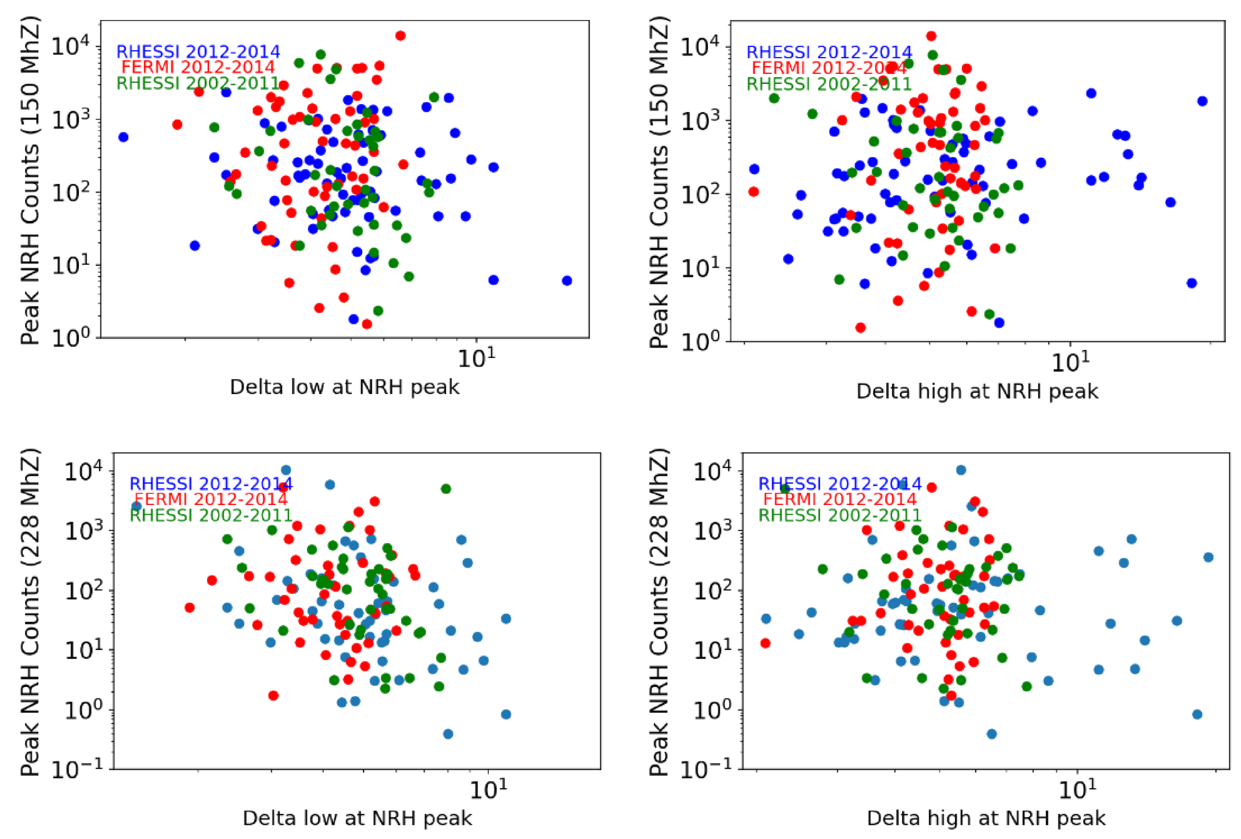

Fig. 3: Correlation plots between electron power law indices derived from a thick target fit to the observed photon spectra and the peak NRH flux at different frequencies.

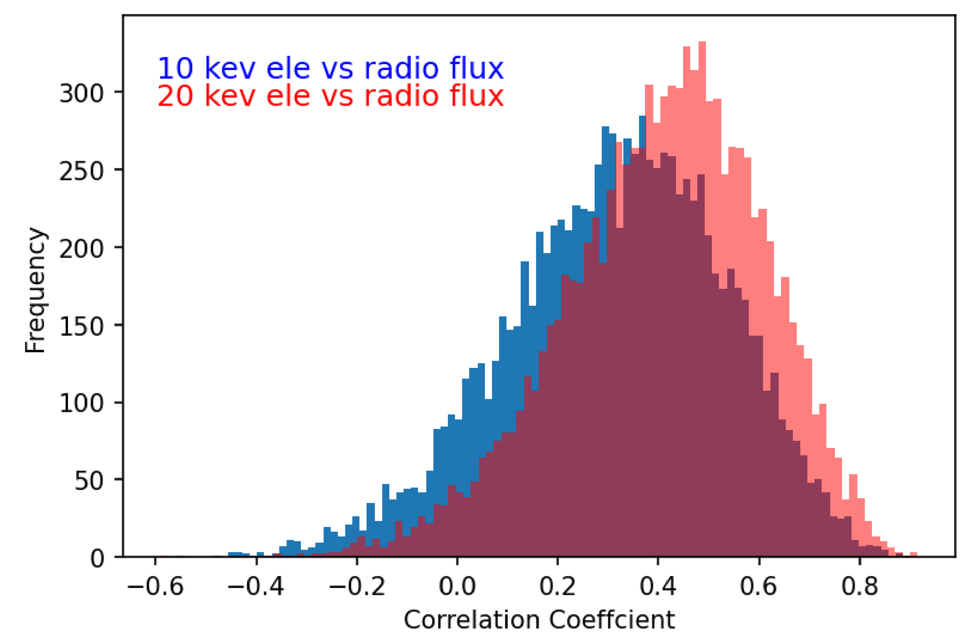

Fig. 4: An example of bootstrap sampling. The number of trials is chosen to be 10000 and the sampling size per trial is fixed at 20.

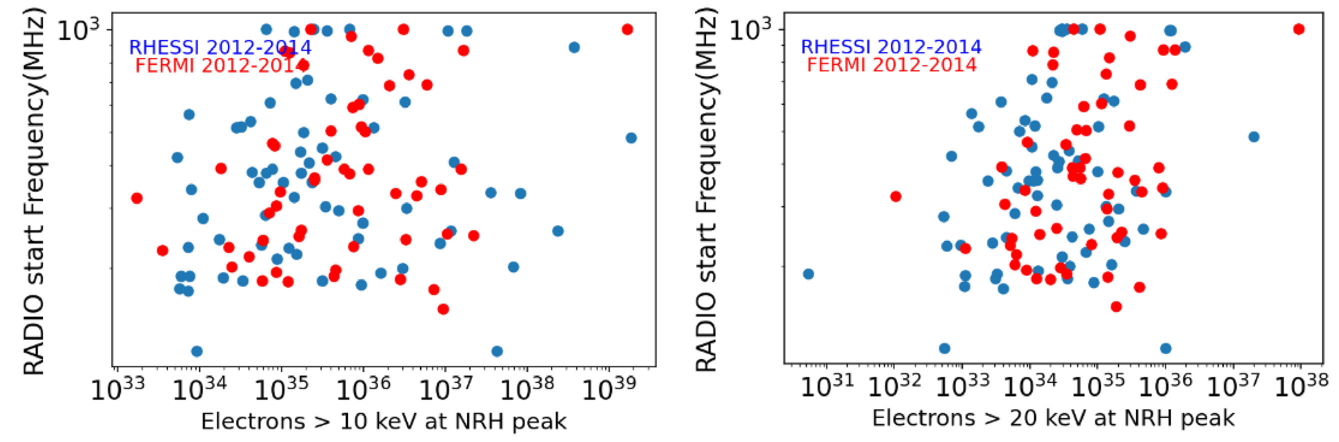

Fig. 5: Scatter plots showing the relation between the number of electrons at 10 and 20 keV electrons and the starting frequency of type III burst from ORFEE spectrometer. The correlation coefficient for 10 keV electrons vs the radio start frequency was found to be 0.17, while for 20 keV electrons were found to be 0.28

Results

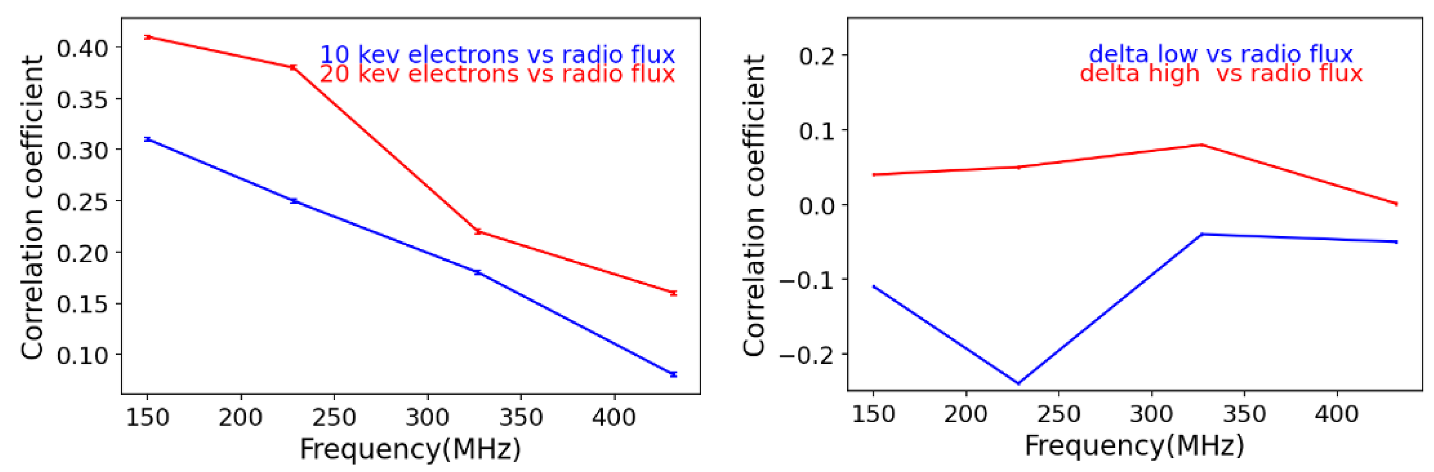

Fig. 6: Left figure shows the relation between the correlation coefficient between the number of electrons and the peak radio flux as a function of frequency. Right figure shows the correlation coefficient between the the electron power law indices and the peak radio flux as a function of frequency.

- We see a montonicaly decreasing correlation between the number of electrons and the type III burst peak flux as a function of frequency. This is in agreement with Reid et.al(2017) study wherein it was showed that the type III bursts are more numerous and stronger at low frequencies than at higher frequencies. This might be because the onset of bump-in-tail instability requiring higher velocity dispersion and for this to happen the electron beam has to traverse to a certain scale height where the density and the local the local plasma frequency would be less.
- The energy spectral index below the break shows a persistent negative correlation. Thus harder(smaller) energy spectra above 20 keV tend to influence the generation of type III burst. This is consistent with previous studies which shows the number density in 20-50 keV electrons is directly proportional to the power output of a type III burst.
- The starting frequency of the type III burst is correlated much more to number of greater than 20 keV electrons than 10 keV electrons. Assuming energy spectra of the HXR electron is equivalent to the energy spectra of the source population which in turn produced the type III burst, this might be an indication that the density of greater than 20 keV electrons in the electron beam travelling upwards influences velocity dispersion

Acknowledgements

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