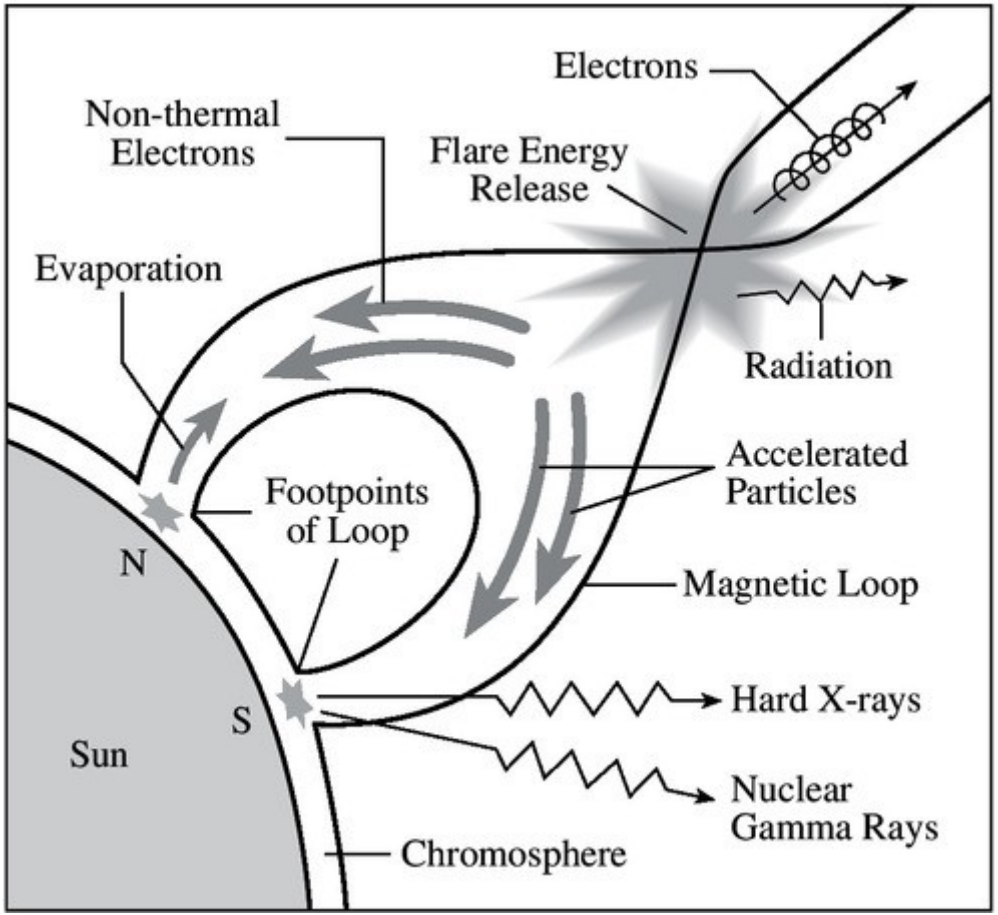
RHESSI Meeting
July 6-9,2021

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

Tomin James
Nicole Vilmer

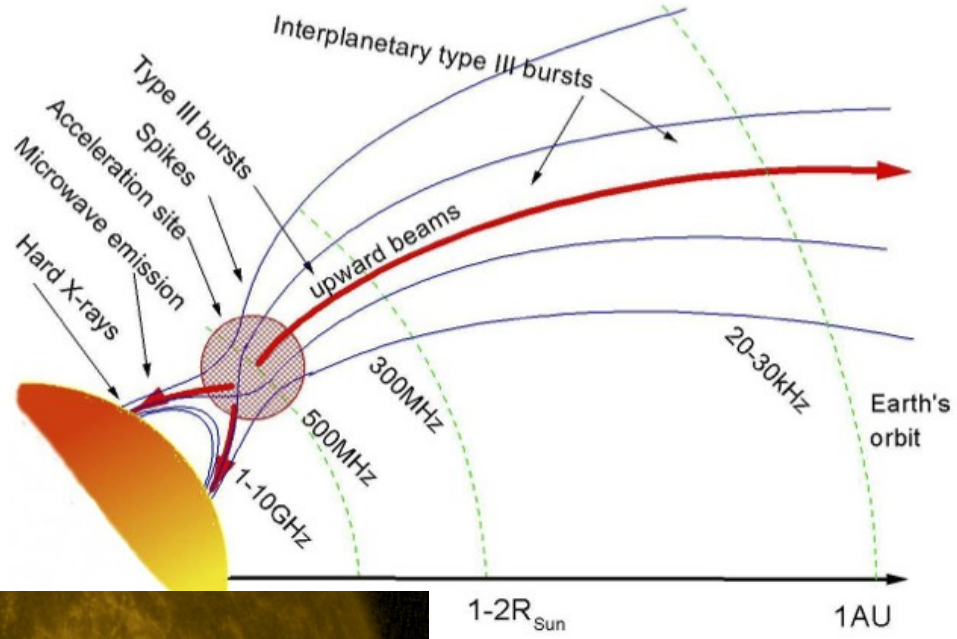
Particle acceleration in solar flares

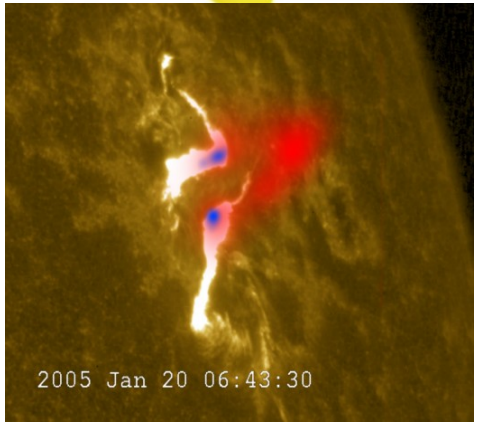


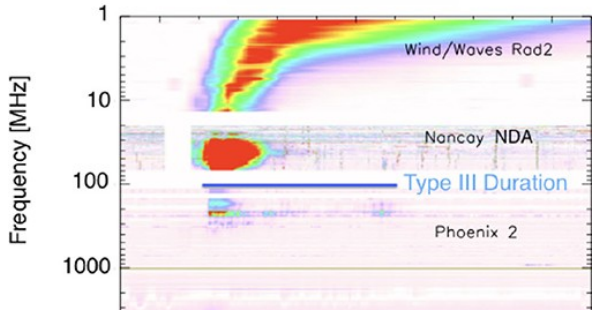
- Electrons are accelerated to high energies in a solar flare.
- Downward bound electrons hits the thick chromosphere and produce HXR radiation.
- Electrons accelerated upwards, produce radio emission at local plasma frequency and its harmonics.

Lang 2010, Vilmer 2012

X-ray and radio emission



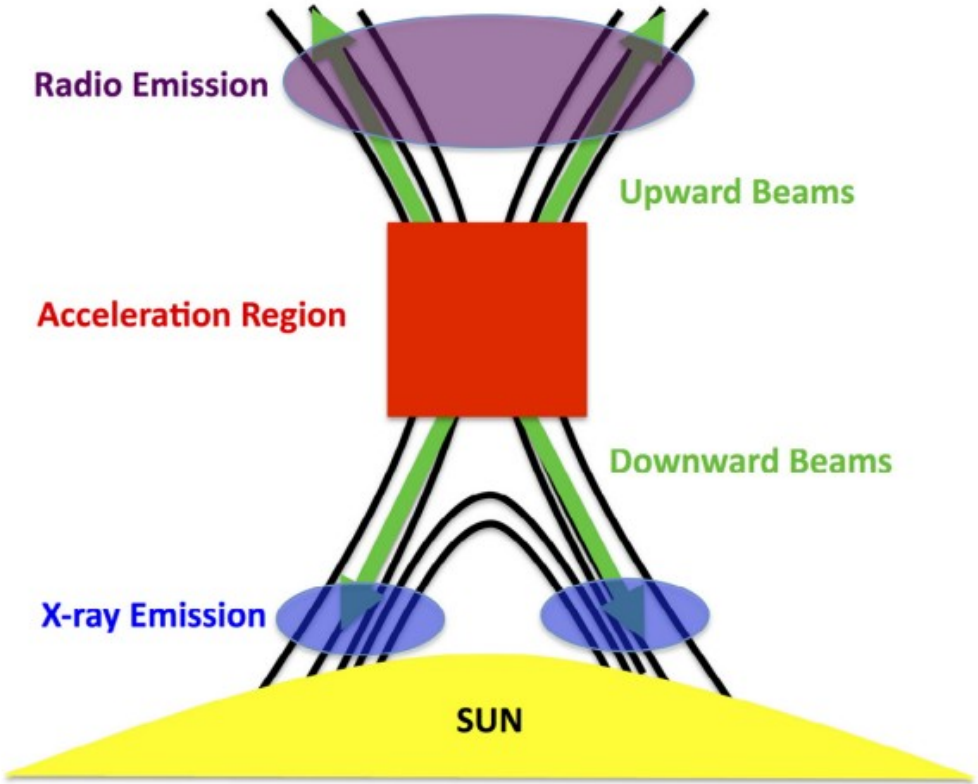




- Energetic particles are a major driver of solar-terrestrial physics and space weather.
- Radio emission from electron beams produced in the solar flares provides crucial information about these energetic particles.
- How are energetic electrons at HXR site and the electrons giving rise to radio emissions connected?

Reid et.al 2014

HXR and RADIO emission site

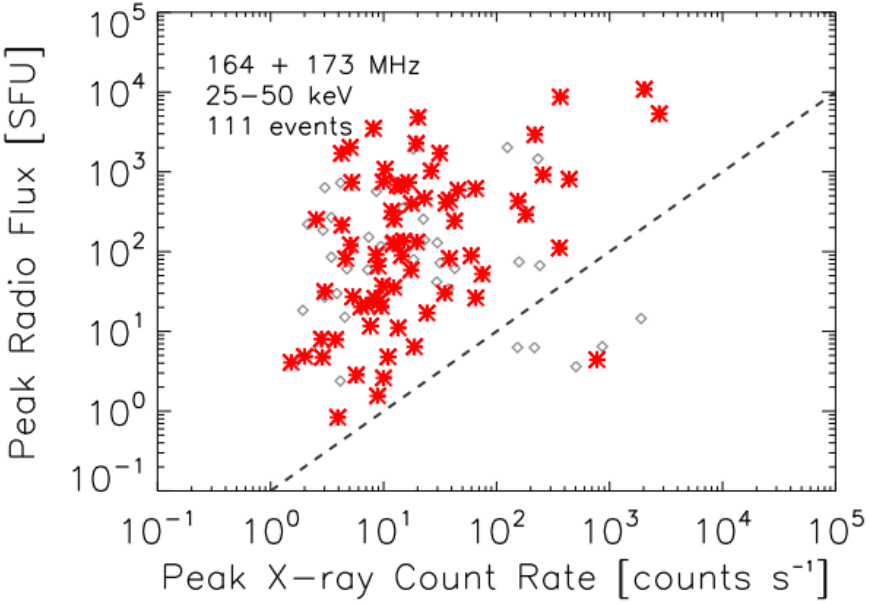


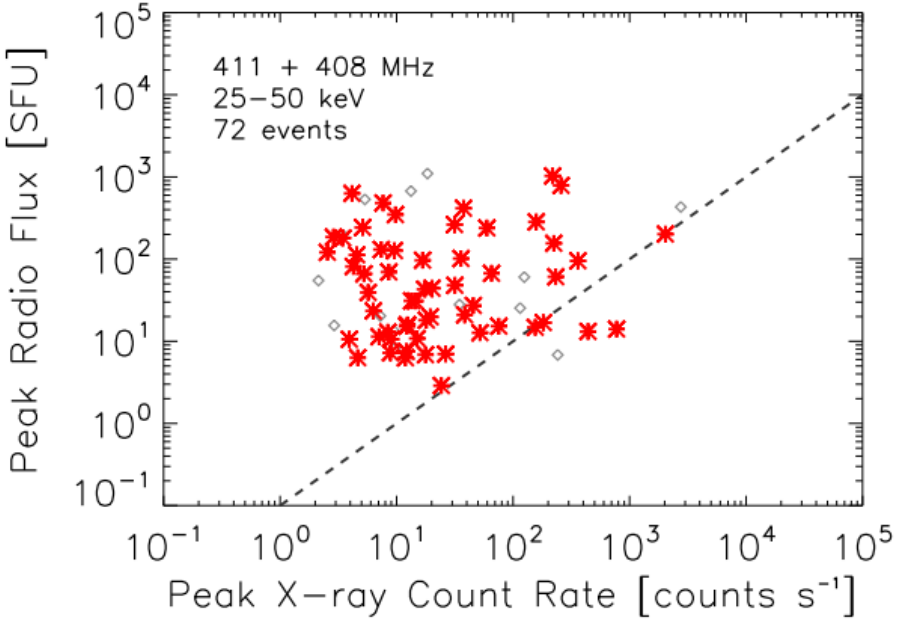
- A simple cartoon relating the HXR emission site and the radio emission site.
- Electron beams are assumed to be simultaneously injected into the chromoshphere and and upper corona.
- Downward travelling beams produce HXR emission while the upward travelling beams produce radio emission.

Reid et.al 2014

Motivation

Statistical study of X-ray count and radio flux of events between 2002-2011





Correlation seen decreasing with increasing frequency – counterintutive !

Reid & Vilmer 2017

Shortlist events with clear X-ray and radio components.

- X-ray flare from RHESSI/FERMI with atleast counts upto 25 kev.

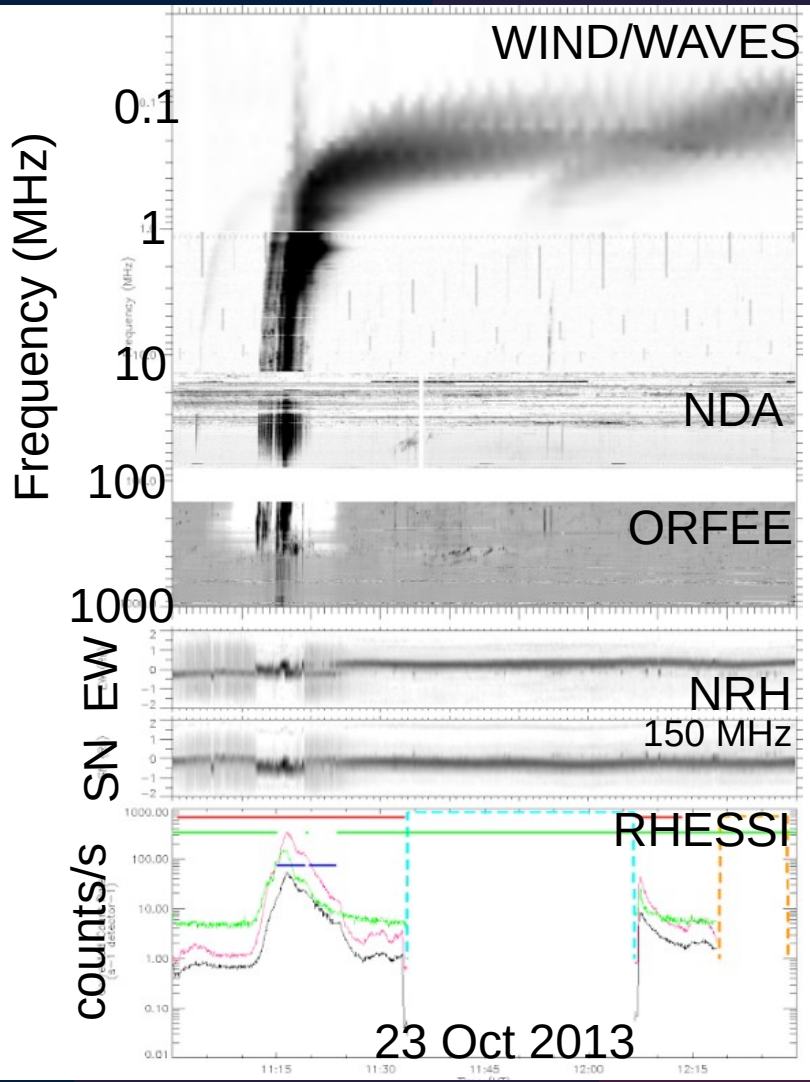
- Type III from a combination of instruments – ORFEES/PHOENIX(> 100 MHz), NDA(10 – 100 MHz) and WIND/WAVES (<10 Mhz).

- Radio flux increase in atleast 150 Mhz frequency component of NRH.

196 events found between 2002-2015.

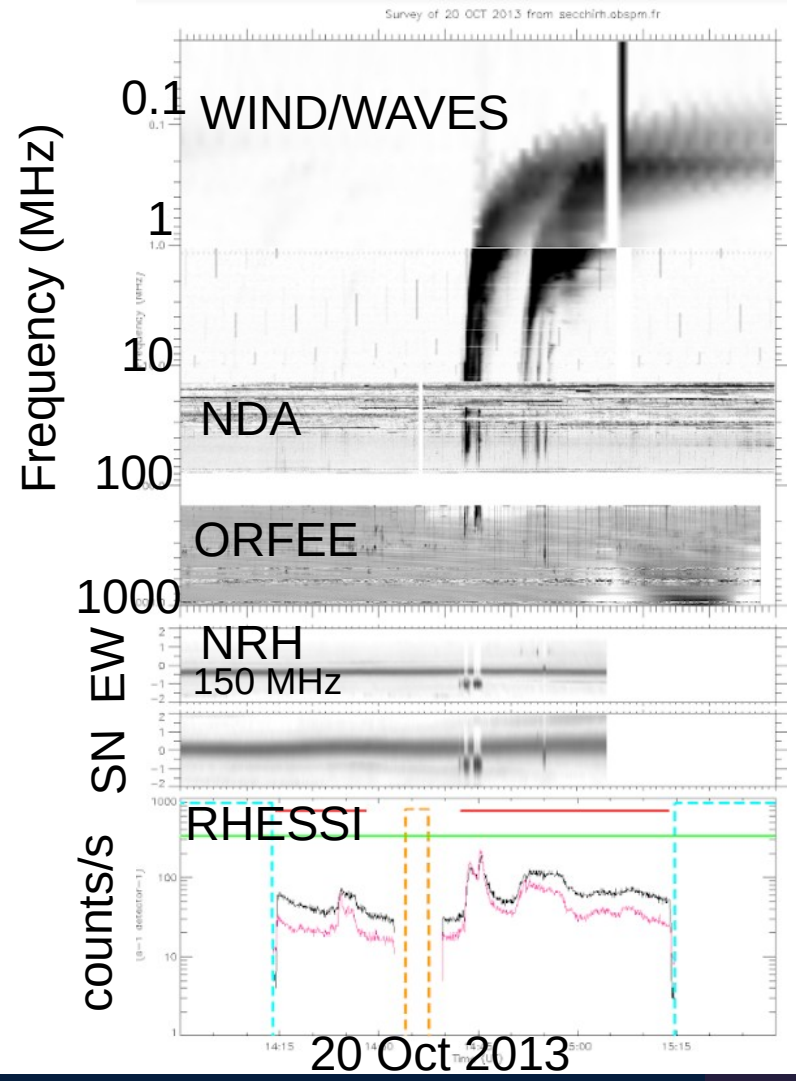
Estimate the number of electrons producing the HXR emission at the at the NRH peak time vs the flux of NRH radio emission.

Timeline of an event

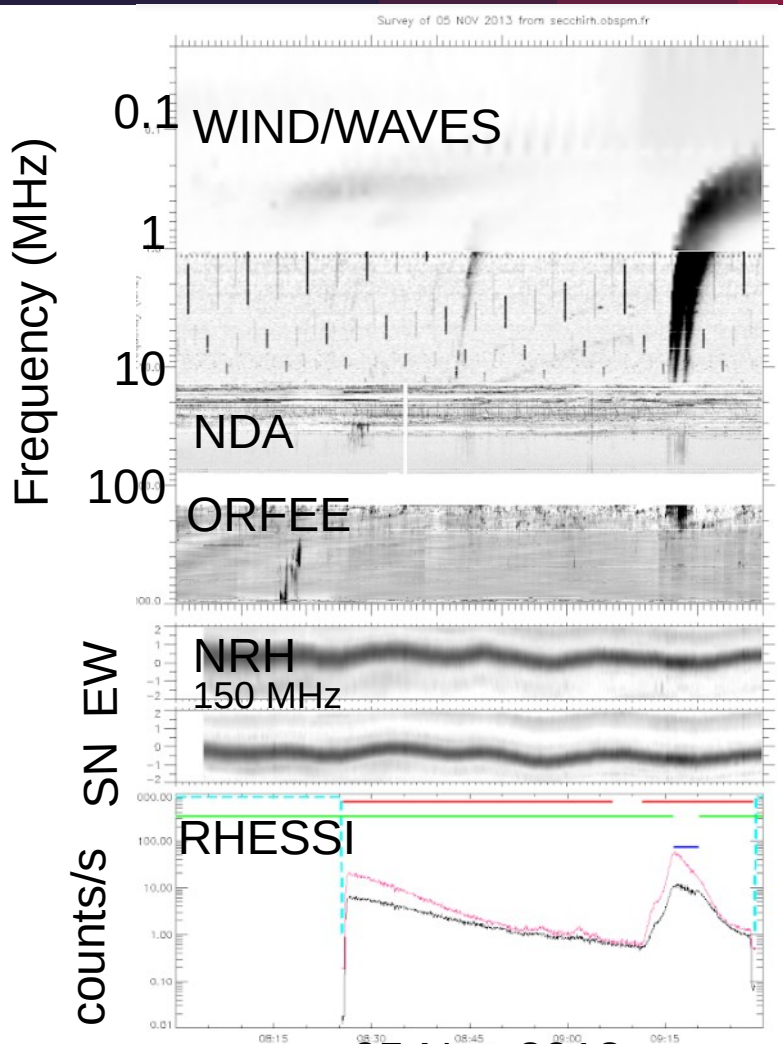


Courtsey: A.Hamani & Aichatou

Examples I

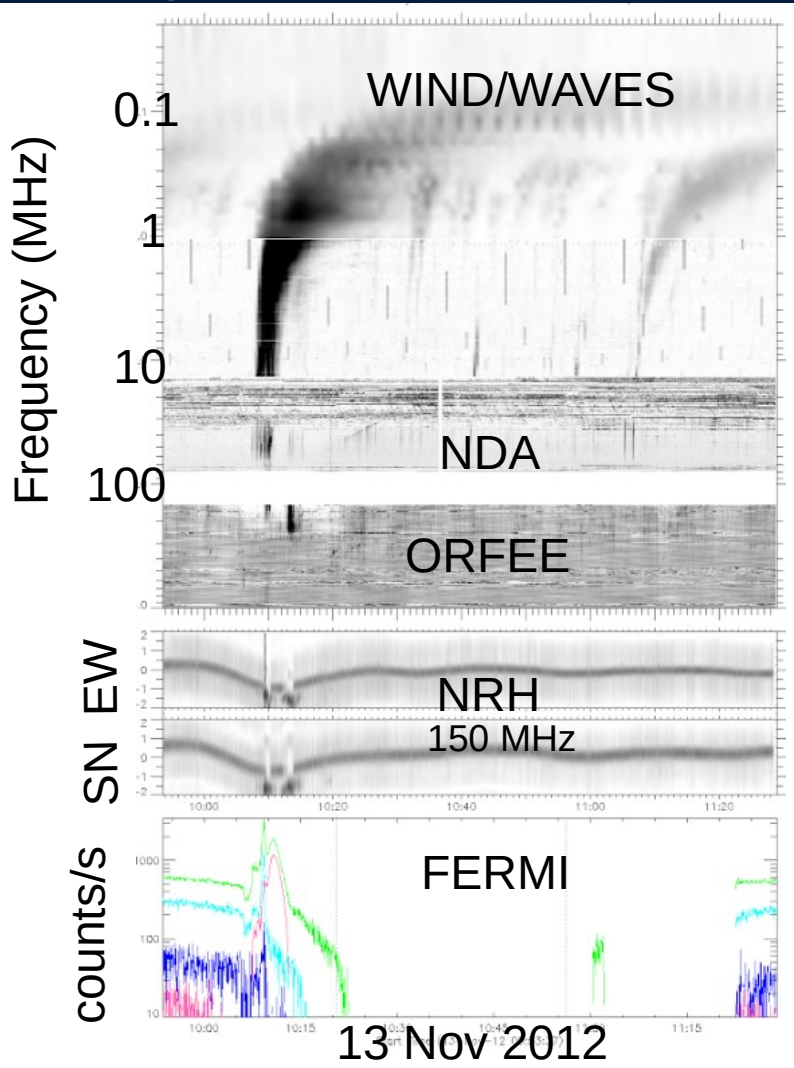


20 Oct 2013

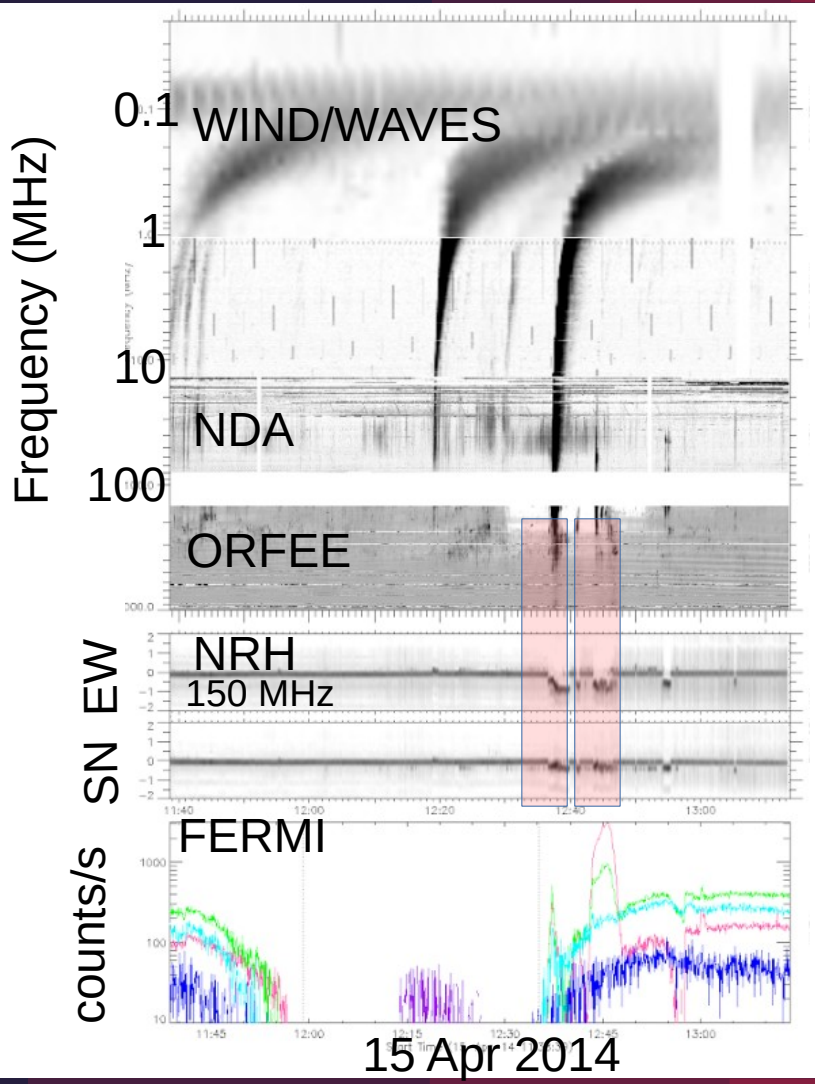


05 Nov 2013

Examples II

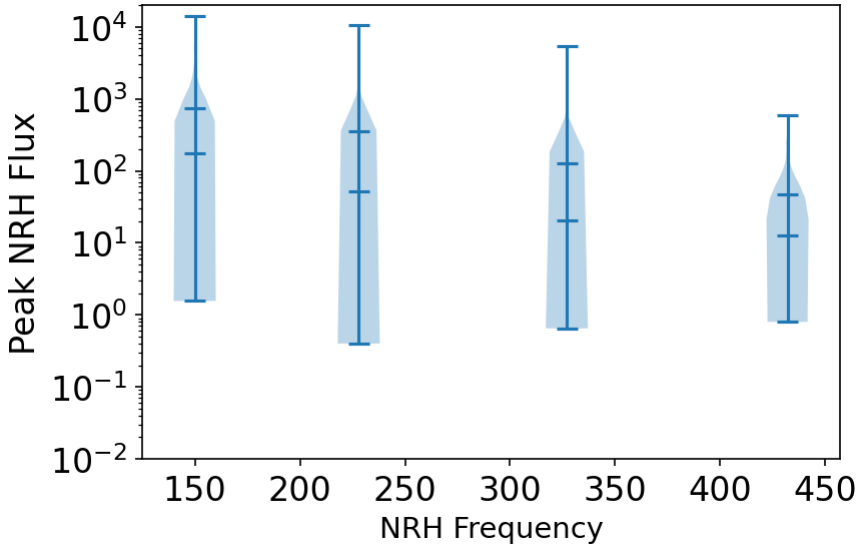


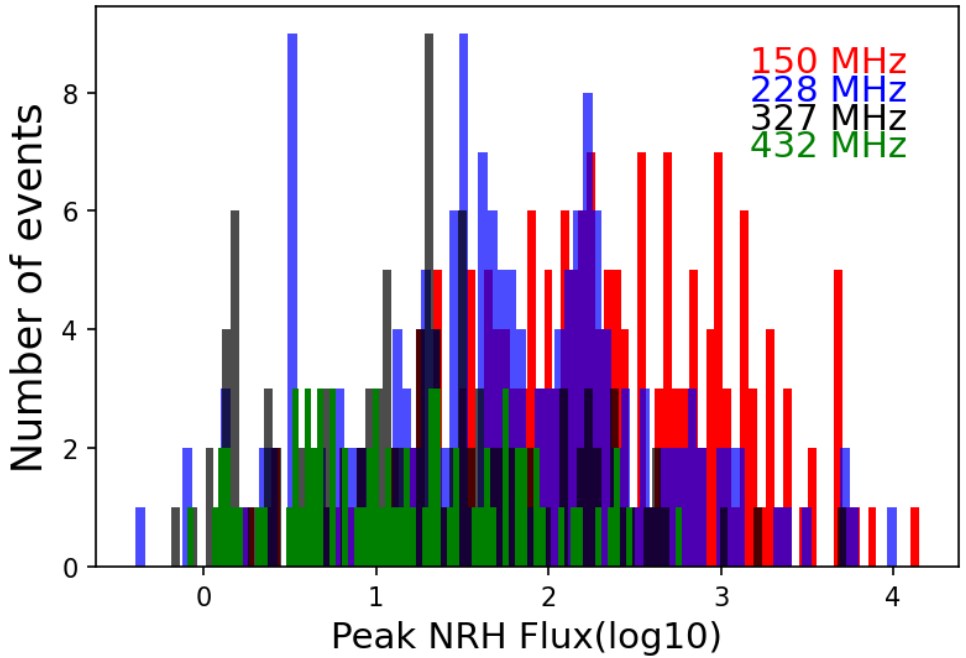
13 Nov 2012



15 Apr 2014

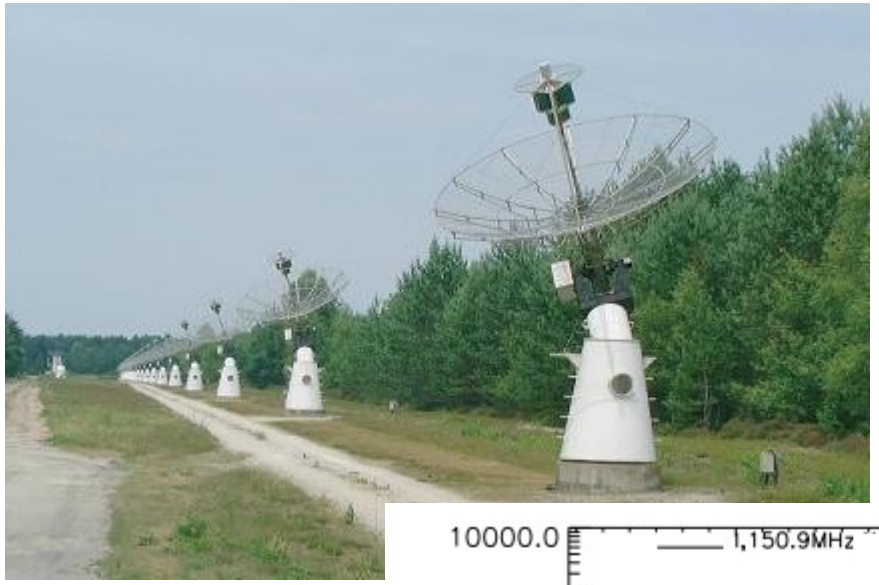
Statistics of the events

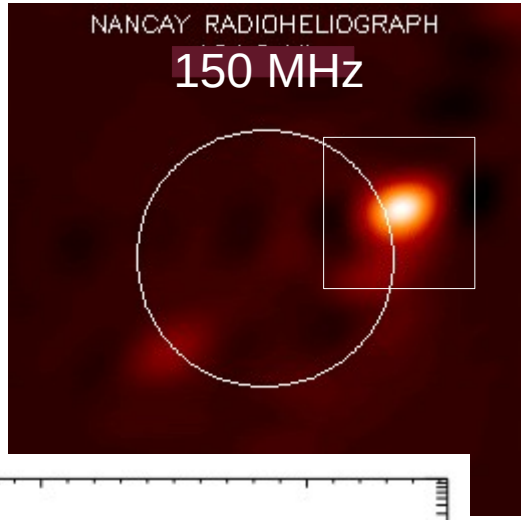


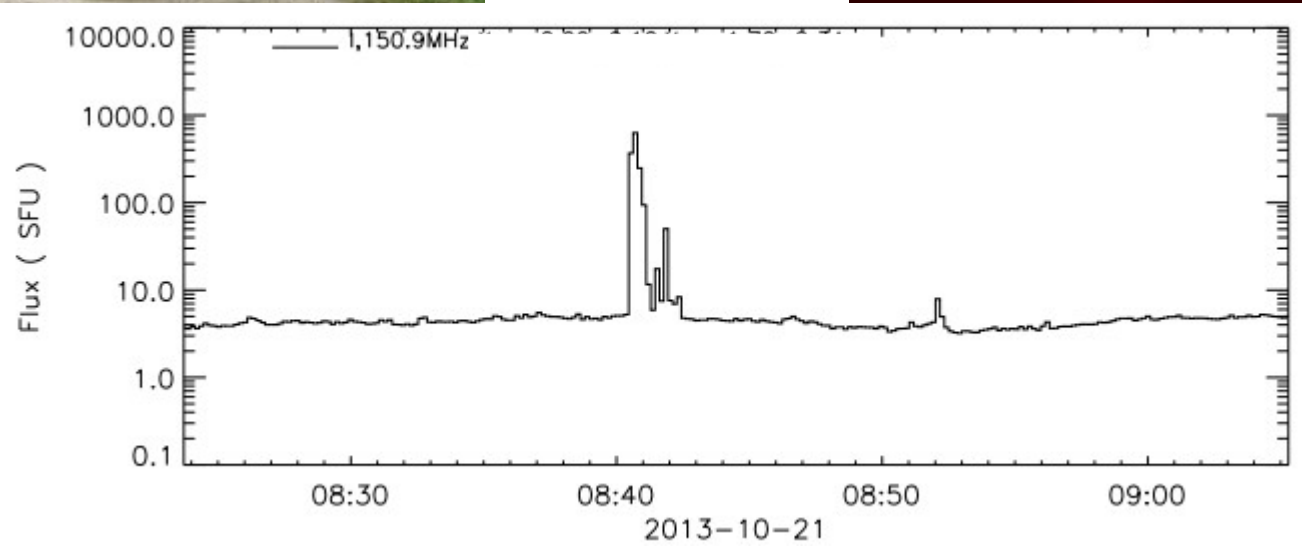


- 86% of the selected events have a IP type III burst associated with it.
- 70% of the events belongs to GOES C class.

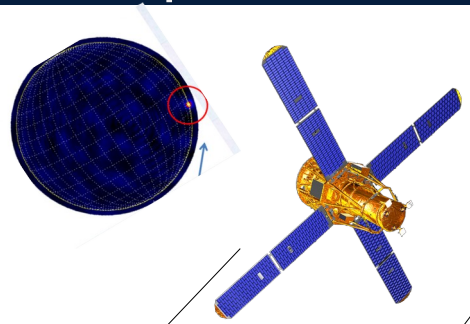
NRH flux

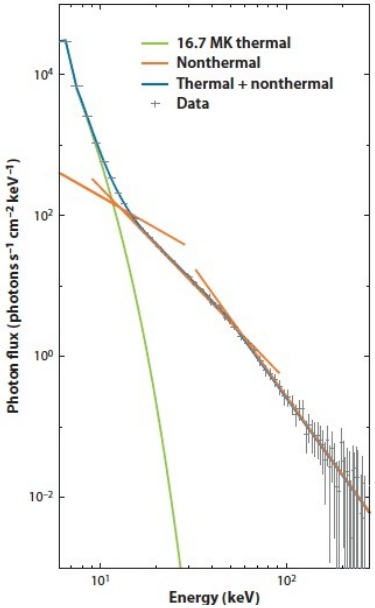


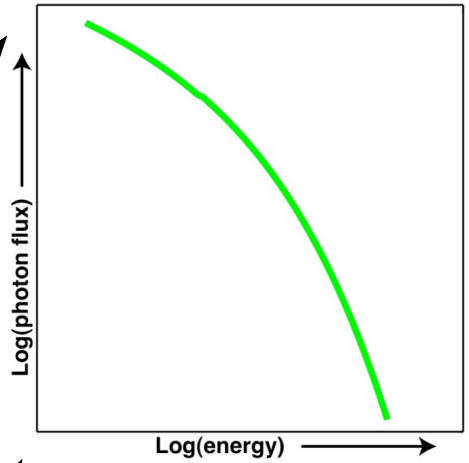

NANCAY RADIOHELIOGRAPH
150 MHz

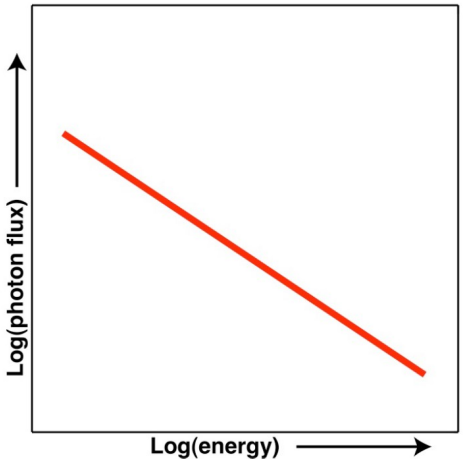

1,150.9MHz
10000.0
1000.0
100.0
10.0
1.0
0.1
Flux (SFU)
08:30
08:40
08:50
09:00
2013-10-21

HXR spectra









$$I(\varepsilon) = \frac{1}{4\pi R^2} \int_{\varepsilon}^{\infty} \int_{V} n(r) F(E,r) Q(\varepsilon, E) dE d^3 r$$

- $I(\varepsilon)$: Photon Flux, ph s^{-1} cm^{-2} keV^{-1}
- $4\pi R^2$: 1 AU
- $n(r)$: Density of background plasma e- interacting with
- $F(E,r)$: e- distribution, e$^-$ cm^{-2} s^{-1} keV^{-1}
- $Q(\varepsilon, E)$: Bremsstrahlung cross-section

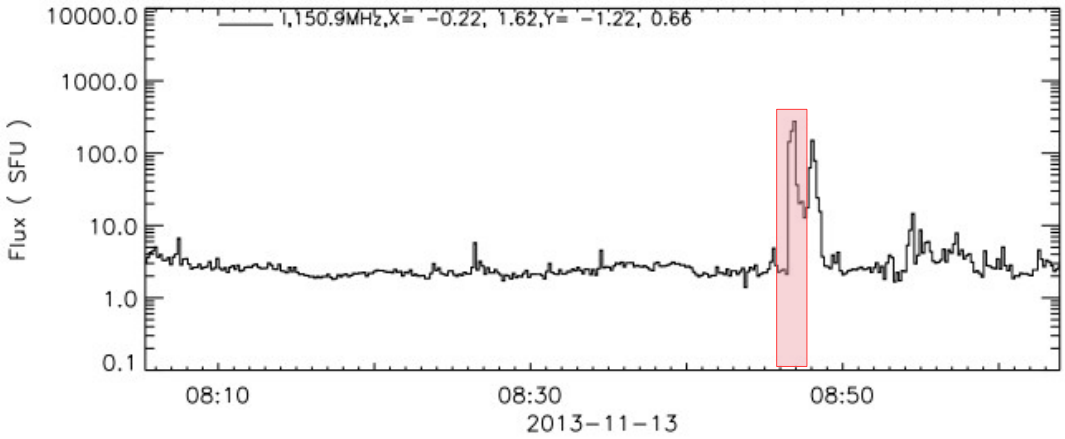
ε =Photon Energy
E =Electron Energy

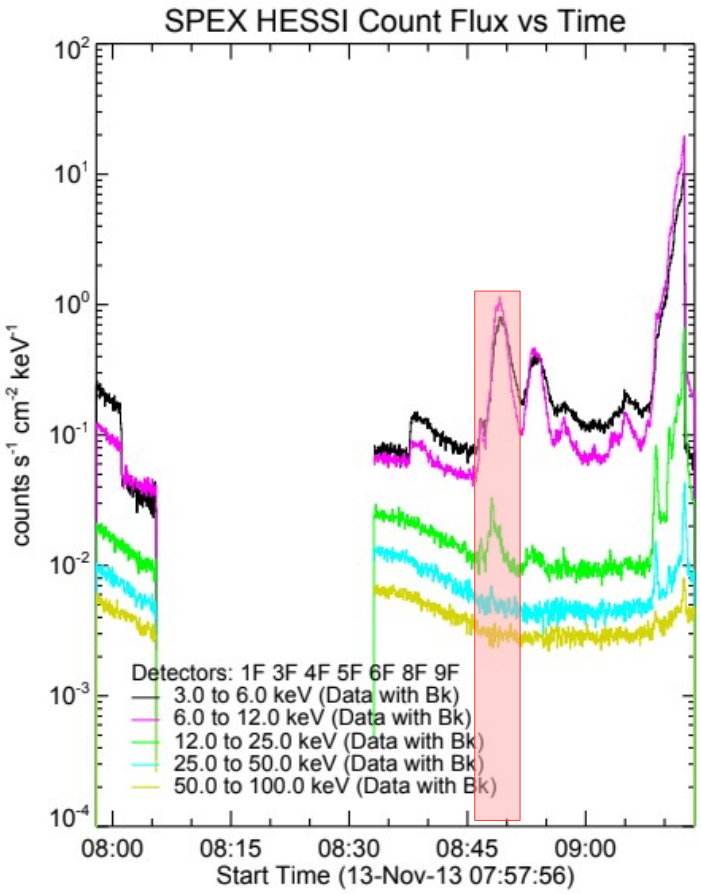
Iso-thermal model

$$I(\varepsilon) \propto Z^2 Q g(\varepsilon, T_e) \frac{\exp(-\varepsilon/k_B T_e)}{\varepsilon\sqrt{T_e}} \quad (\text{photons/s/keV}) \quad \text{where} \quad Q \equiv \int_V n_e^2 dV$$

Brown 1971,1974; Lin 1974

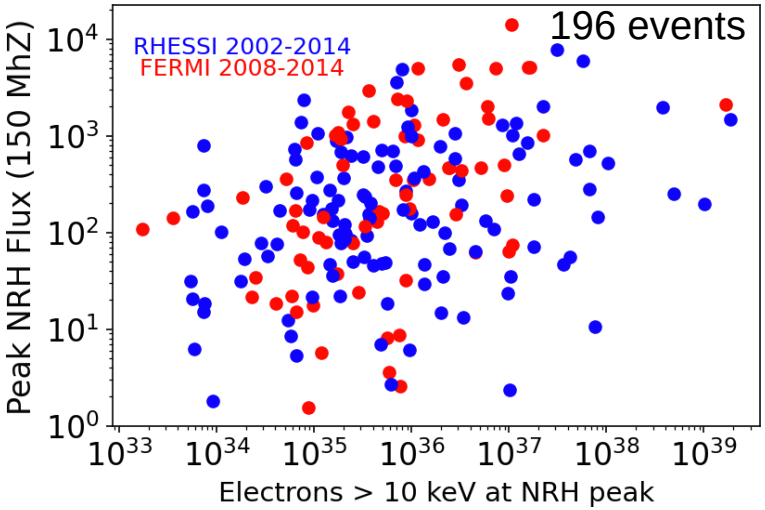
HXR timings

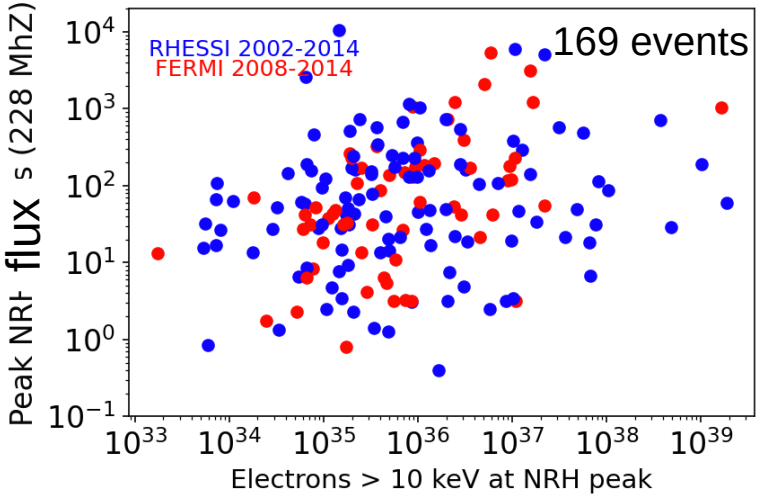


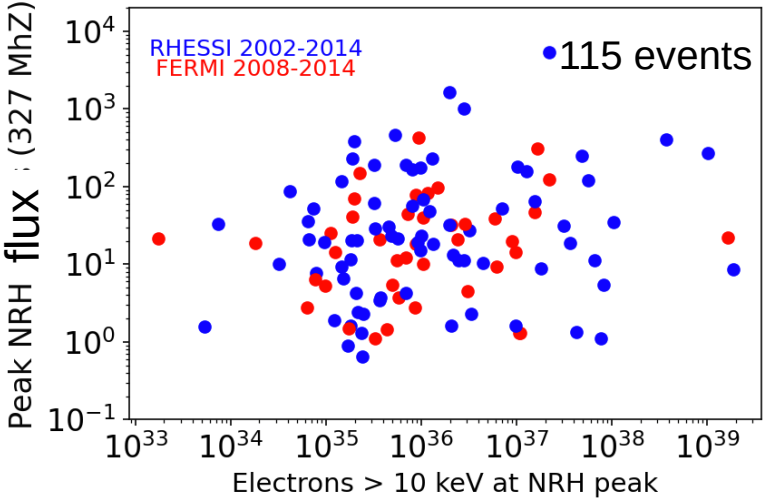


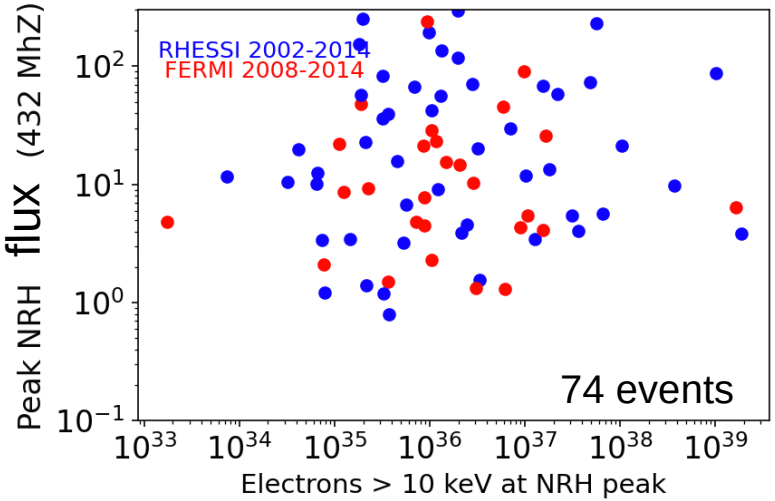
HXR spectra is calculated at the peak of the NRH flux at 150 MHz.

No: of electrons vs Peak radio flux I

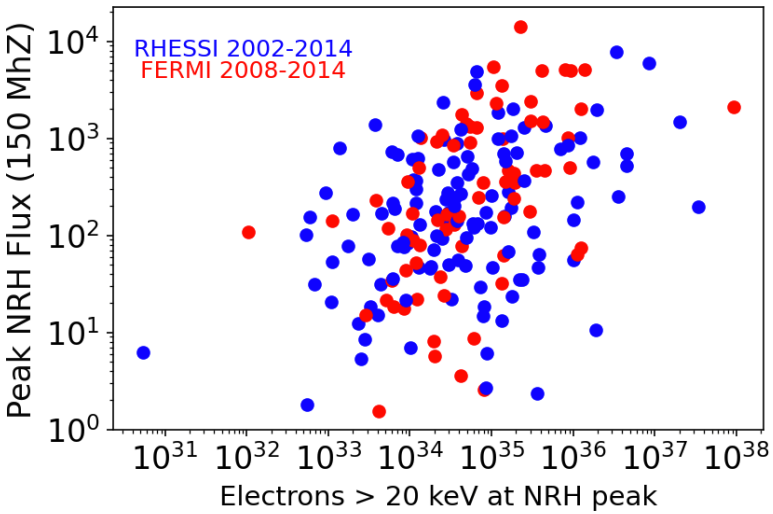


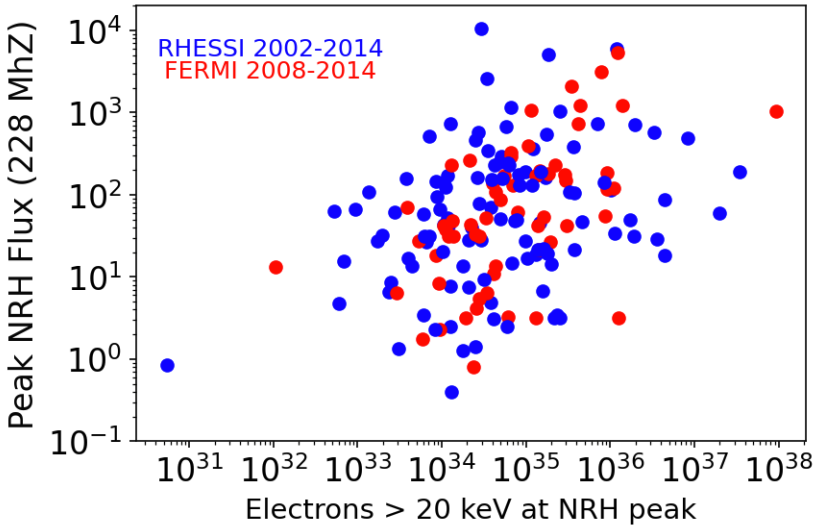


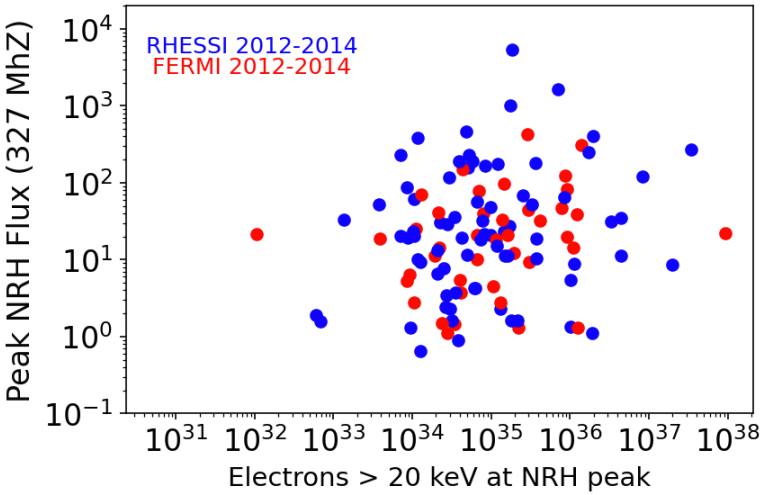


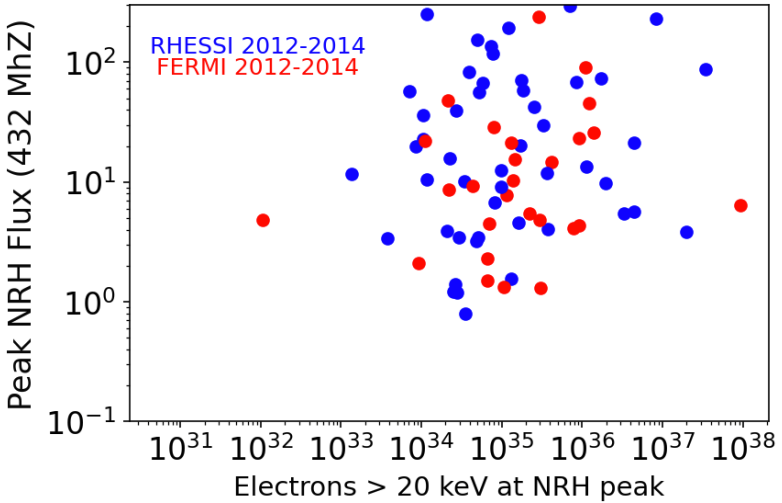


No: of electrons vs Peak radio flux II

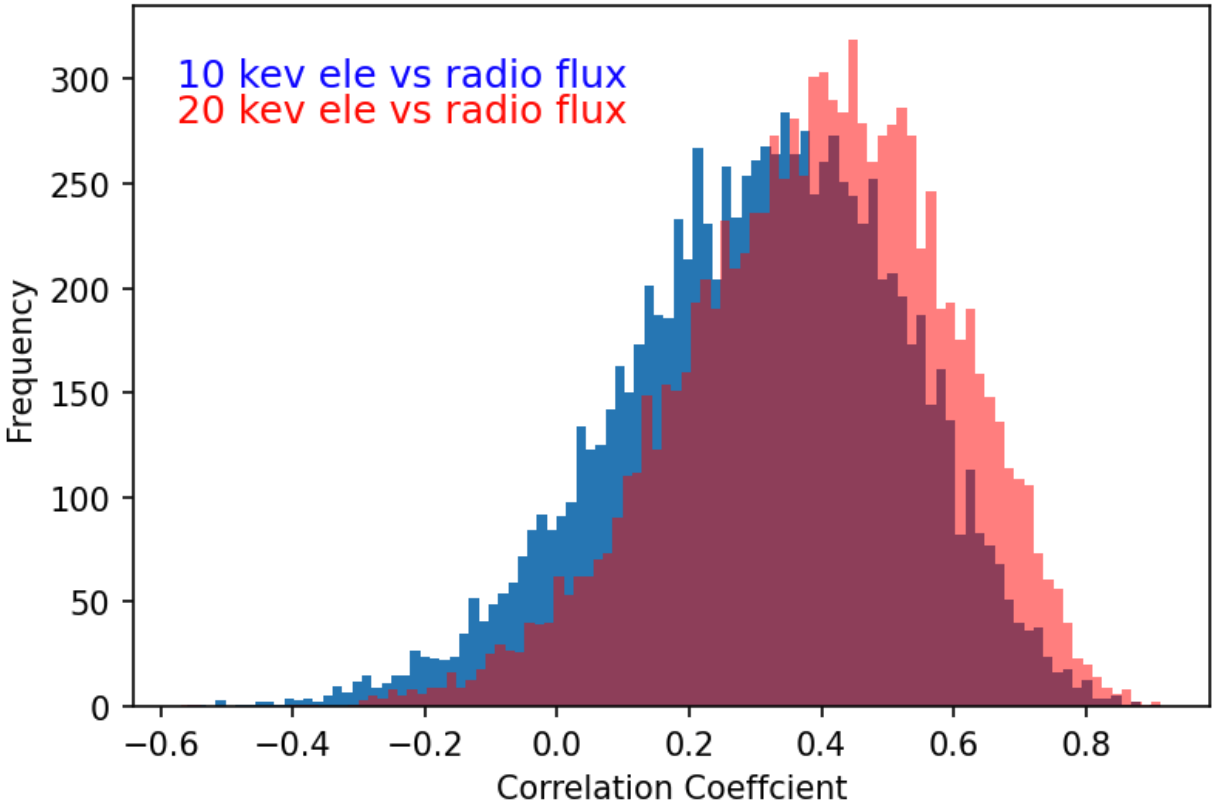








Error analysis in CC

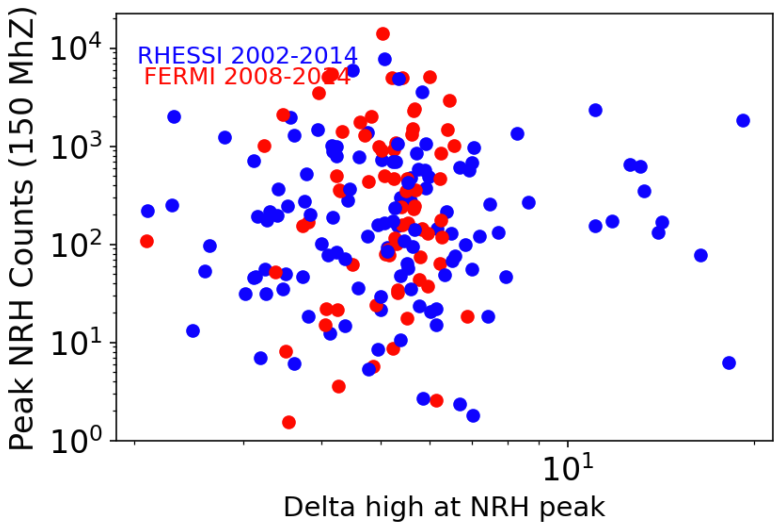


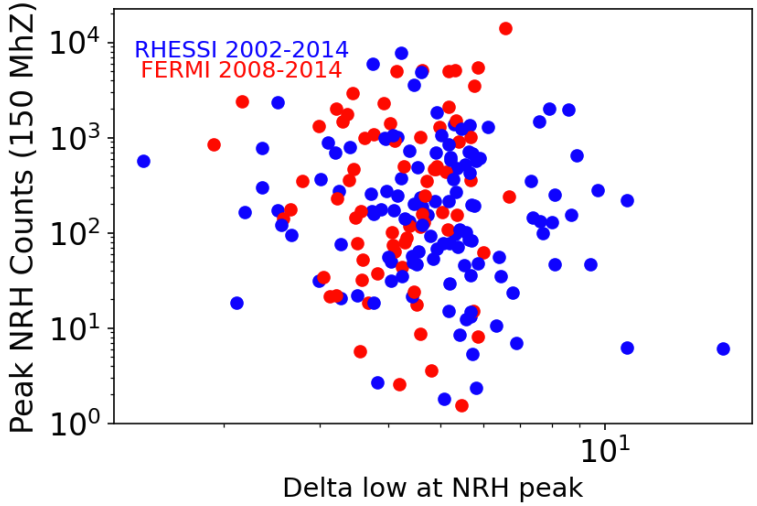
Spearman's Correlation

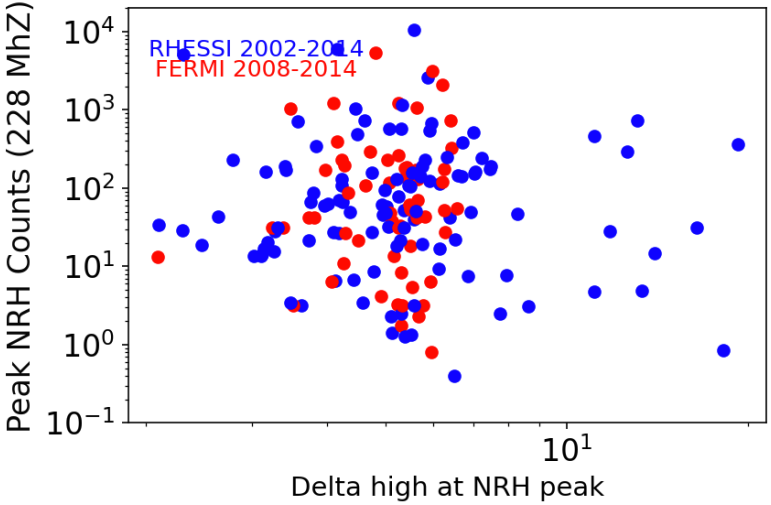
$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$$

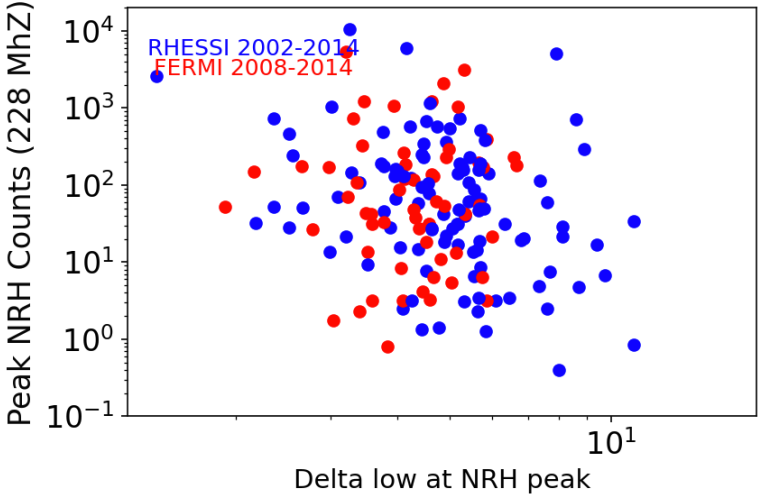
Spearman's correlation coefficient, ρ,measures the strength and direction of association between two ranked variables.

Electron spectral index vs Radio flux

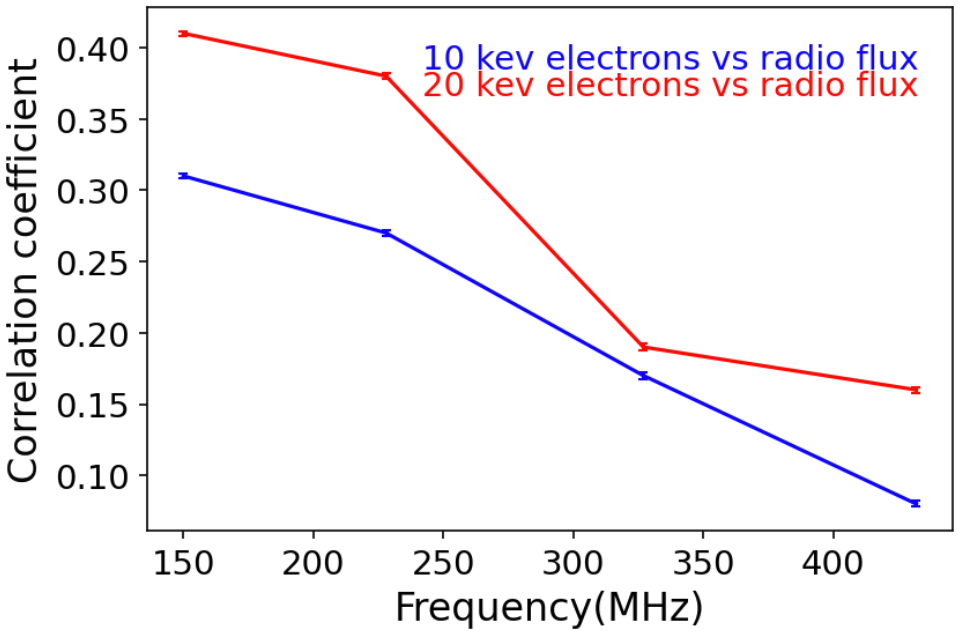






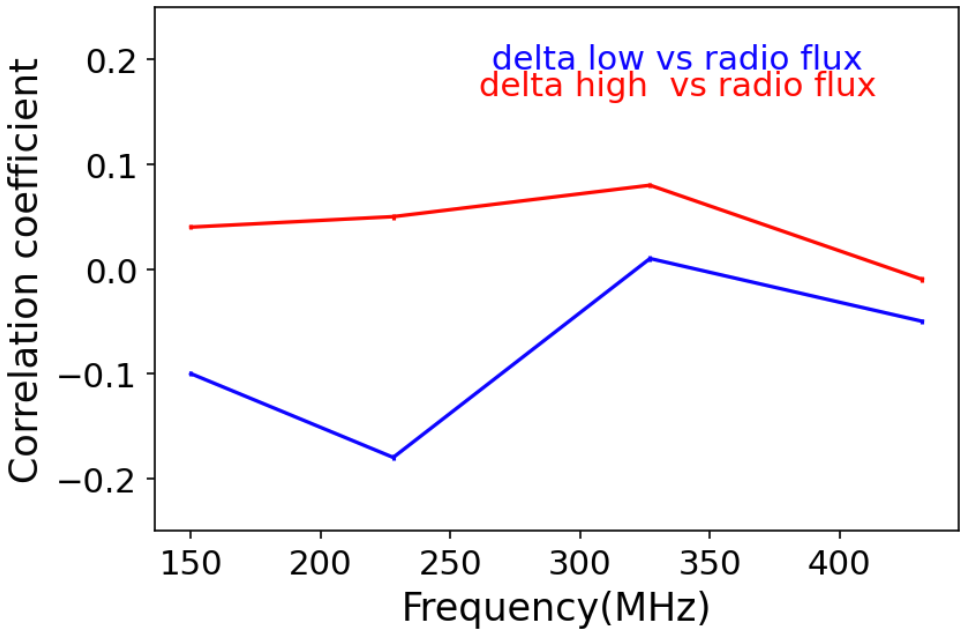


Correlation vs Radio frequency



Correlation monotonically decreases with frequency.

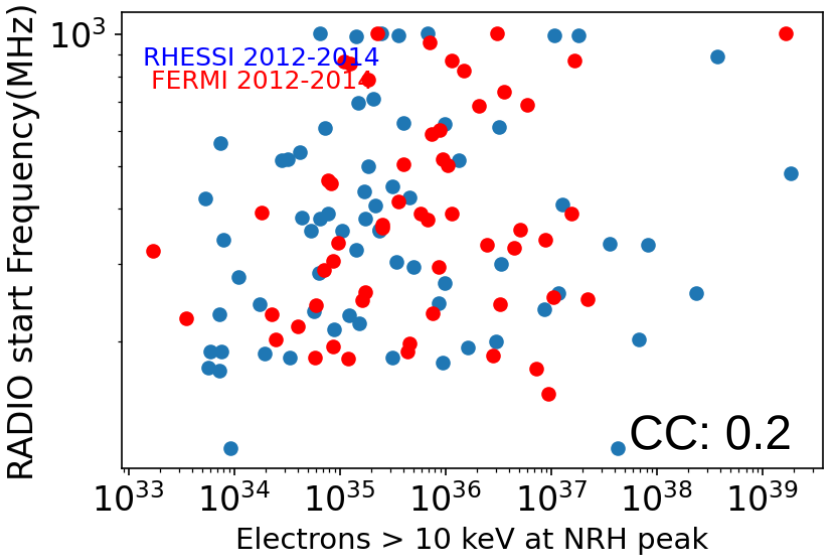
Number of electrons> 20 keV at the peak of 150 Mhz emission of NRH has higher corr. at all frequencies.

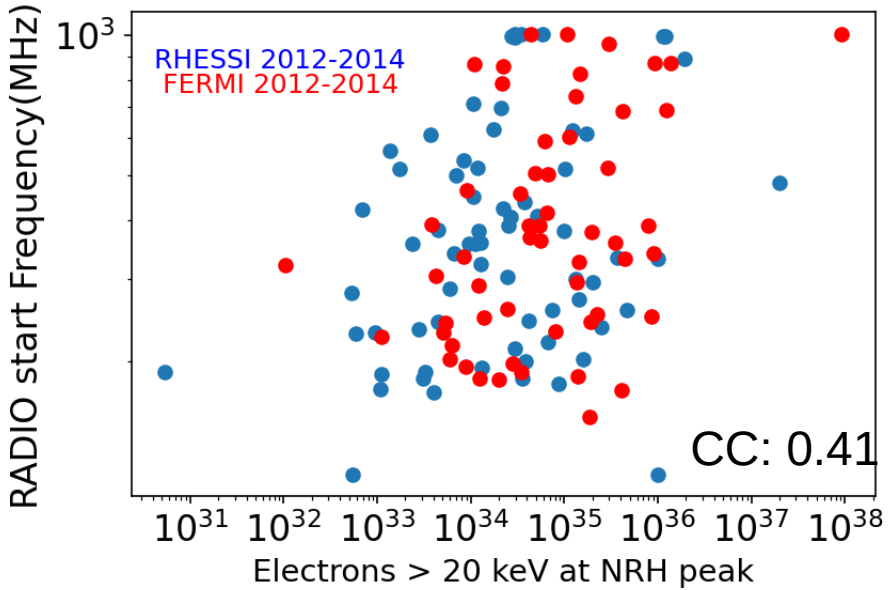


No major correlation between power law above the break and the peak radio flux.

Persistent negative correlation at lower frequencies for power law below the break and the peak radio flux.

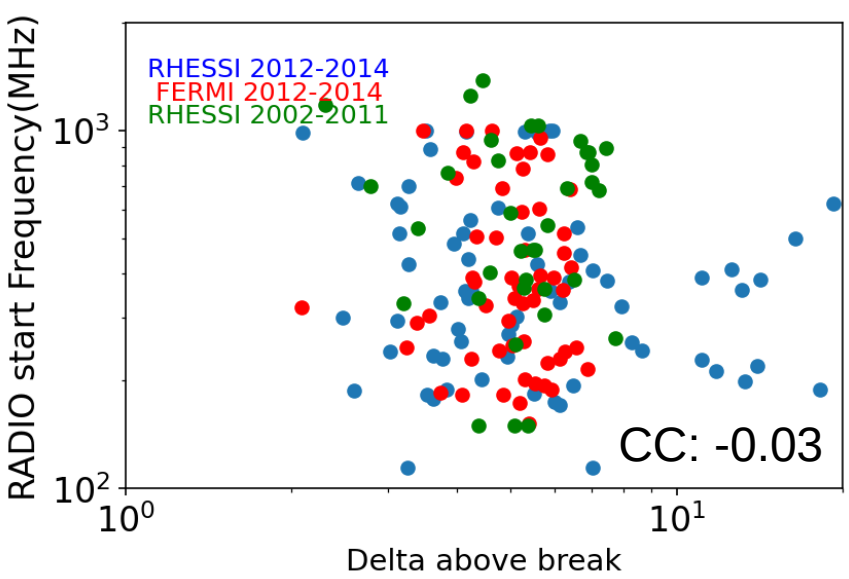
Starting Freq vs No: of electrons

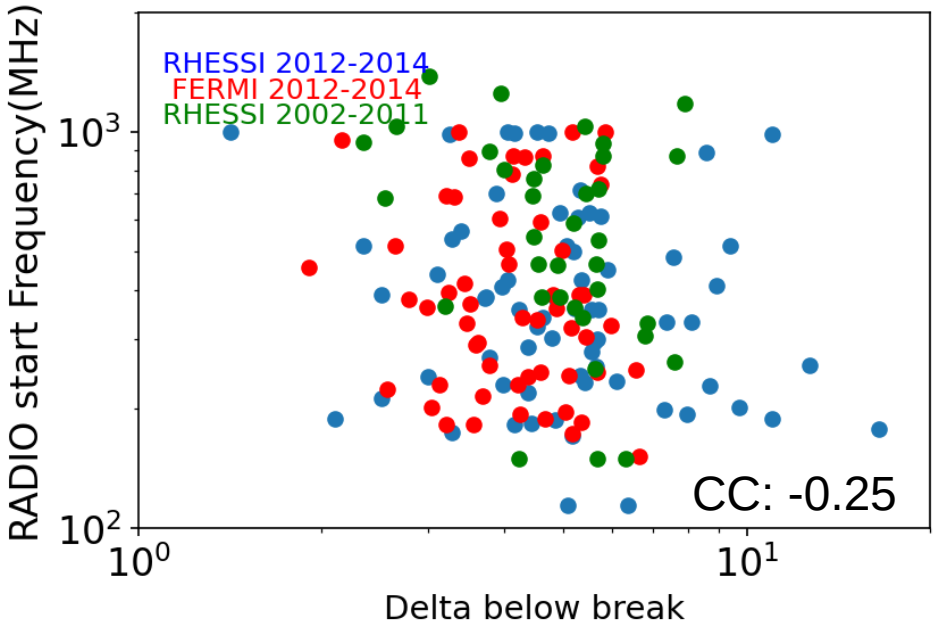




Starting frequency of type III radio bursts is more correlated with the number of electrons above 20 Kev at the time of the peak of 150 Mhz emission than those above 10 kev.

Starting Freq vs ele. Spectral index





Delta indices above the break have little correlation with the starting frequency of type III radio burst. Delta indices below the break show anti-correlation with type III starting frequenices.

Summary and conclusions

- We studied the statistical correlation between HXR electrons and the electrons responsible for producing the type III radio bursts. We see a montonically decreasing correlation between the number of electrons and the type III burst peak flux at increasing frequencies. This is in agreement with Reid et.al(2017)

This might be indicating a certain scale height for the bump-in tail instability to kick in

Summary and conclusions

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- We also looked at the energy spectral indices of the electron spectrum producing the HXR emission and the peak fluxes of the type III burst at different frequencies. The energy spectral index below the break shows a persistent negative correlation.

Harder(smaller) energy spectra above 20 kev tend to influence the generation of type III burst. Number density in 20-50 kev electrons is directionally proportional to the power output of a type III burst. Is this pointing to the same parent seed population for HXR electrons and radio electrons?

Summary and conclusions

- The starting frequency of the type III burst is correlated muchmore to number of greater tha

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

Better constraints for simulation studies.


Thank you