Gamma-ray Imaging of the 2005 January 20 Solar Flare

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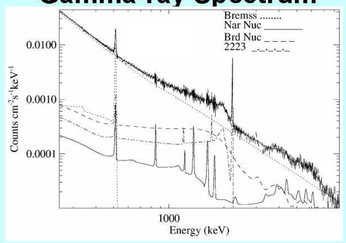
Introduction

- Solar gamma-rays are produced by flare-accelerated ions and electrons interacting with the ambient solar atmosphere.
- Solar gamma-ray emission provides the only way to observe accelerated ions near the Sun.
- The 20 January 2005 Xxxx flare had an exceptionally hard accelerated particle spectrum.
- This poster summarizes the results of RHESSI gamma-ray imaging for this event.

Summary

- The 250-500 keV electron-bremsstrahlung emission came from two compact sources of similar intensity that corresponded to the TRACE 1600A footpoints on opposite sides of a neutral line.
- This was in contrast to the 2223 keV neutron-capture line emission originated from a single compact source, less than 20 arcsec FWHM, that corresponded to just one of the footpoints.
- Preferential association of nuclear emission with the northerly footpoint was supported by imaging in the gamma-ray continuum where the emission centroids were closer to the northerly footpoint in energy bands with stronger relative contributions from nuclear interactions.

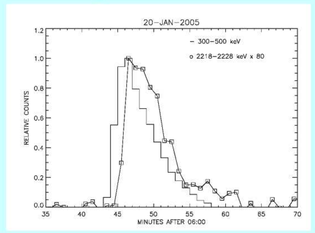
Gamma-ray Spectrum



Modeling the observed gamma-ray count spectrum (top) can identify its individual components:

- Electron-bremsstrahlung (……..)
- Prompt narrow lines from accelerated protons and ambient ions (_____)
- Prompt Doppler broadened lines from accelerated ions and ambient protons (- - - -)
- Positron-annihilation line at 511 keV (. . . .)
- Very narrow neutron-capture line at 2223 keV from the capture of thermalized neutrons by ambient protons. (. _ . _ . _)
- Enhanced count spectrum below the 511 and 2223 keV lines is from photons that deposit only part of their energy in the detector and from 3-photon positron annihilation.

Light Curves

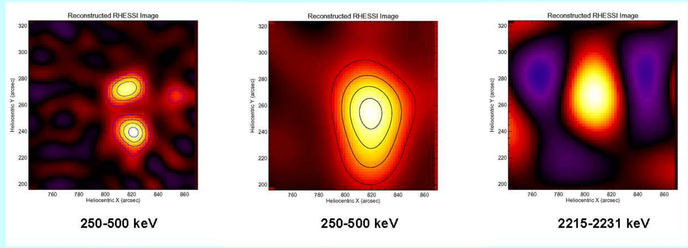


- 250-500 keV light curve is dominated by electron-bremsstrahlung emission.
- 3500-7000 keV light curve includes a significant ion component from prompt nuclear interactions.
- Their similarity suggests similar time scales for electron and ion acceleration.
- The neutron-capture line curve shows a characteristic ~!00 second delay due to the neutron thermalization time.
- Images in this poster integrate over the full flare from 06:44 to 06:56..

RHESSI Gamma-ray Imaging

- RHESSI imaging uses a set of 9 rotating modulation collimators (RMCs) with logarithmically-spaced FWHM angular resolution from 2.3 to 183 arcseconds. RMCs 6 and 9 (35 and 183 arcsec) can modulate at gamma-ray energies.
- 9 segmented germanium detectors provide 1 to 5 keV resolution from 3 to 17000 keV.

Neutron-Capture Line Imaging

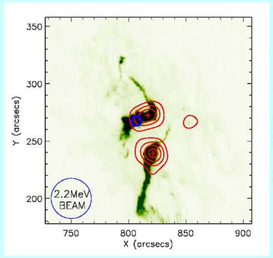


250-500 keV 250-500 keV 2215-2231 keV

Above left: 250-500 keV high resolution (12 arcsec resolution) image made with RMCs 4-9 shows the electron-bremsstrahlung emission coming from 2 compact sources of comparable intensity.

Middle: The 250-500 keV image made with only RMC 6+9 (35 arcsec resolution) is consistent with the high resolution image, but the 35 arcsecond RMC cannot resolve the footpoints. As a result, the map shows a single elongated source, centered between the two unresolved components.

Right: The 2215-2231 keV RMC 6+9 neutron-capture line map with the same resolution also appears as a single source. However, the spatial displacement from the 250-500 keV image (middle) is evident. All three maps have the same 128x128 arcsec field of view and were made with the same imaging parameters.



TRACE 1600A
06:52:30 UT

250 – 500 keV
30, 50, 70, 90% contours

2215-2231 keV centroid
1-σ error circle

Overlay of 250-500 keV electron-bremsstrahlung and 2223 keV neutron capture line maps on a TRACE image. The two stronger electron-bremsstrahlung sources correlate well with the TRACE footpoint emission. The centroid of the neutron-capture line source is clearly associated with the northerly footpoint. In addition there is an additional easterly displacement of the neutron-capture line centroid along the footpoint from the lower energy emission.

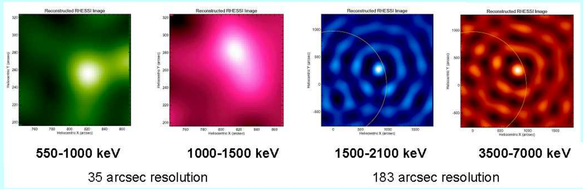
Neutron-Capture Line Statistics

- An estimate of the size of the neutron-capture line source can be obtained by comparing the number of spatially-integrated counts between 2215 and 2231 keV (from the spectrum) with the intensity of the imaged source.
- Background for the spatially integrated background is determined from the nearby continuum. RMC Imaging does not respond to unmodulated background.

2215-2231 keV 06:44 – 06:56	RMC 6	+-	RMC 9	+-
Total Counts	961	31	518	23
Counts from background or continuum	245	8	206	7
Spatially integrated line counts	716	32	312	24
Imaged Counts	705	189	290	62
Imaged / Spatially integrated Counts	**0.98**	0.27	**0.93**	0.21

The ratios of imaged counts to spatially integrated counts for RMC 6 and 9 are consistent with 1, indicating that the sources are unresolved. Assuming a gaussian source profile, the values imply that the **2-σ upper limit to FWHM source size is 20 arcsec**.

Gamma-ray Continuum Imaging

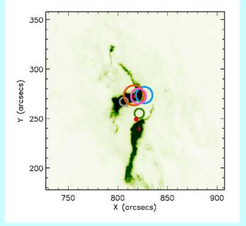


550-1000 keV 1000-1500 keV 1500-2100 keV 3500-7000 keV

35 arcsec resolution 183 arcsec resolution

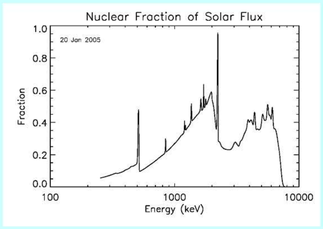
Images in the gamma-ray continuum bands (above) do not resolve the sources.

Their centroid locations are shown below with 1-sigma error circles and superimposed on the TRACE image below. The higher energy bands tend to be associated with the northerly footpoint.

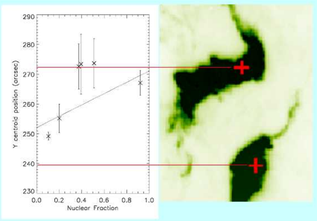


3500 -7000 keV
2215 -2231 keV
1500 -2100 keV
1000 -1500 keV
550 -1000 keV
250 –500 keV

The relative contribution of electron-bremsstrahlung and nuclear interactions to the gamma-ray count spectrum is energy dependent, as shown in the figure below. (Figure is derived from spectrum at left).



A plot of the northerly position of the centroid emission as a function of the relative nuclear contribution is shown below.



It shows that the centroid of the electron-bremsstrahlung source is midway between the footpoints, whereas the location of continuum energy bands with larger nuclear components are more closely associated with the northerly footpoint. The line is a predication based on the assumption that all the nuclear flux originates in the northern footpoint.