Hard X-ray Microflares down to 3 keV

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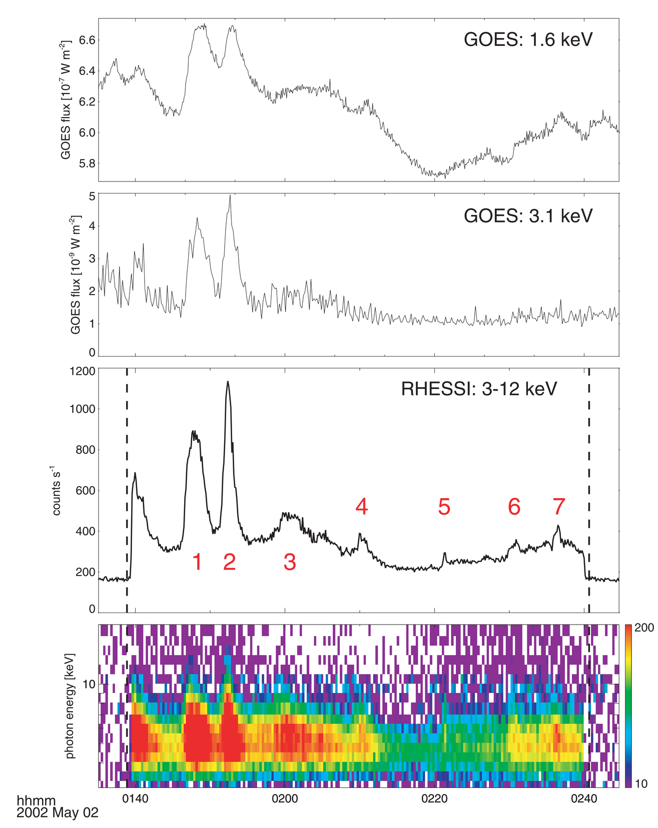
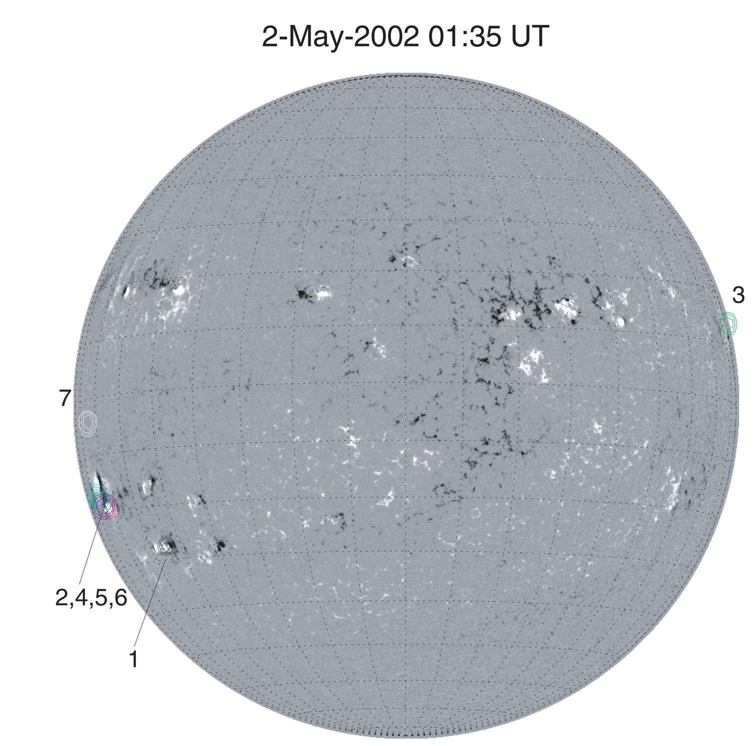
The excellent sensitivity, spectral and spatial resolution, and energy coverage down to 3 keV provided by the Reuven Ramaty Solar Spectroscopic Imager mission (RHESSI) allows for the first time the detailed study of the locations and the spectra of solar microflares down to 3 keV. During a one hour quiet interval (GOES soft X-ray level around B6) on May 2, 1:40-2:40UT, at least 7 microflares occurred with the largest peaking at A6 GOES level. The microflares are found to come from 4 different active regions including one behind the west limb. At 7" resolution, some events show elongated sources, while others are unresolved point sources. In the impulsive phase of the microflares, the spectra can generally be fitted better with a thermal model plus power law above ~6-7 keV than with a thermal only. The decay phase sometimes can be fit with a thermal only, but in some events, power law emission is detected late in the event indicating particle acceleration after the thermal peak of the event. The behind-the-limb microflare shows thermal emissions only, suggesting that the non-thermal power law emission originates lower, in footpoints that are occulted. The power-law fits extend to below 7 keV with exponents between -5 and -8, and imply a total non-thermal electron energy content between 10^{26}-10^{27} ergs. Except for the fact that the power law indices are steeper than what is generally found in regular flares, the investigated microflares show characteristics similar to large flares. Since the total energy in non-thermal electrons is very sensitive to the value of the power law and the energy cutoff, these observations will give us better estimates of the total energy input into the corona.

During one hour of observation at least 7 microflares were seen by RHESSI.

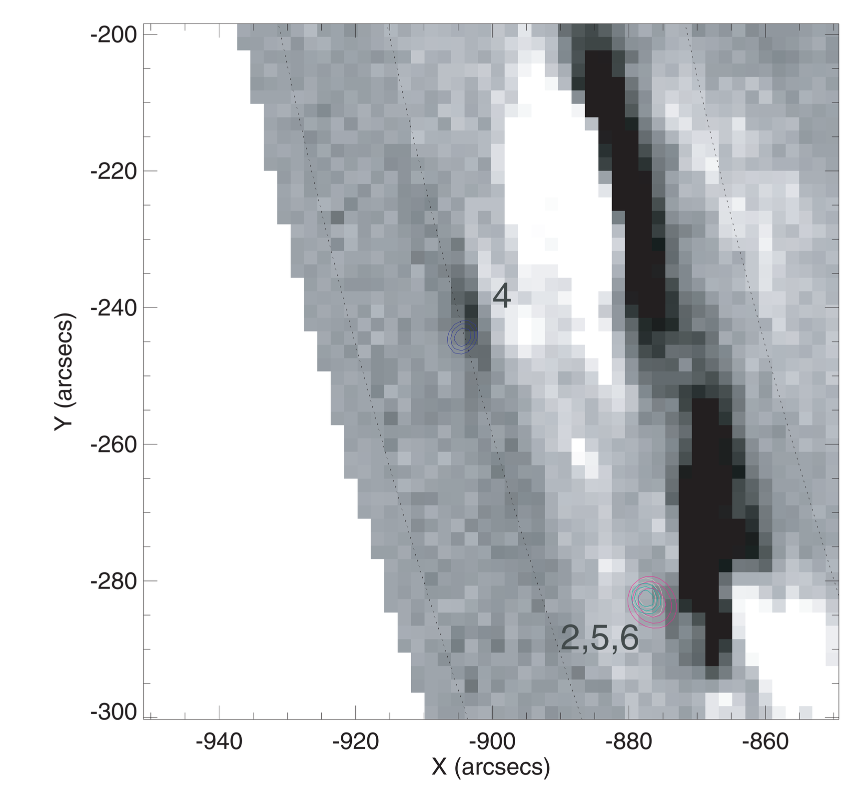
From the top to bottom, the panels show the softer and harder GOES channel plotted in a linear scale, the RHESSI X-ray total uncalibrated counts between 3 and 12 keV, and the RHESSI count spectrogram plot (background subtracted). The microflares studied in detail are marked with numbers.



The microflares were distributed among 4 active regions. Flare 3 is believed to have occured behind the limb, a fact supported by a purely thermal spectrum. Flare 7 occured in a small active region not yet visible on this magnetogram.



A close up of the most energetic region shows that 3 flares are possibly related to the same magnetic loop system.



Spectra of the first three flares were analyzed.

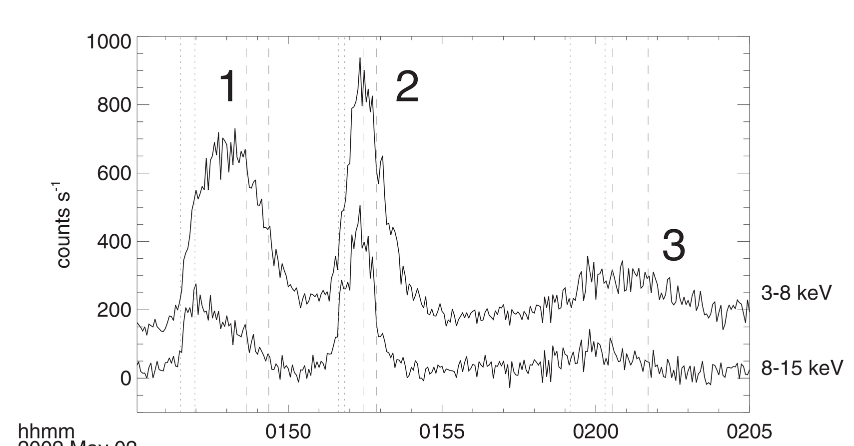
The relatively low number of counts and the absence of a wide range in energy where non-background counts are detected make fitting of the microflare spectra challenging. Microflares are typically seen from 3 keV up to 15 keV, giving only 12 data points to fit a function with 5 parameters.

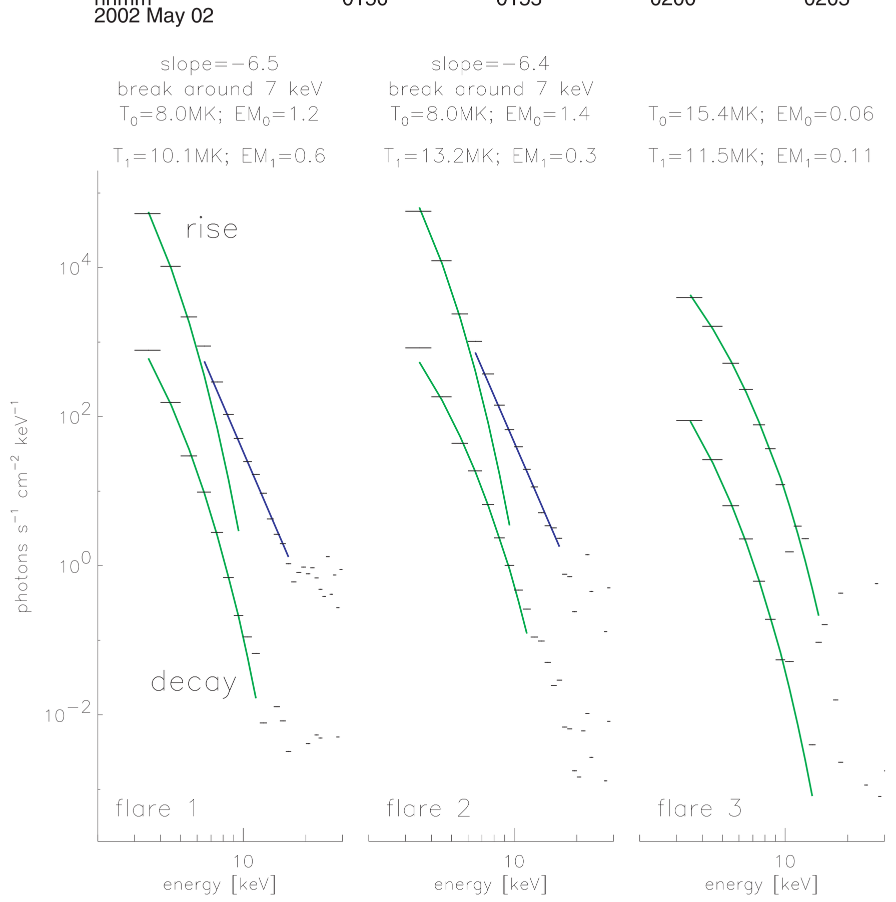
The following spectra are obtained by subtracting the night time background for microflares 1 and 2 and the pre-event background for microflare 3.

For flare 1 and 2, the rise phase shows a steep power law while the decay phase shows only thermal emission.

Flare 3 shows thermal emission during both rise and decay. The X-ray source is thought to be occulted.

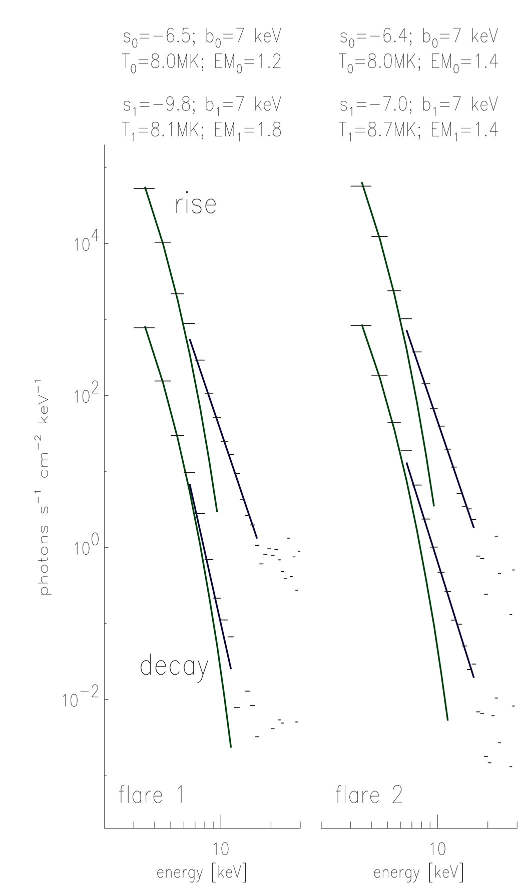
The accuracy of the derived power law index lies within ±0.5 from multiple fits. The derived temperature is less accurate with an uncertainty of ±2 MK.





For comparison, the decay phase of flare 1 and 2 were fit with both a power law and thermal.

Flare 2 seems to show non-thermal emission during the decay phase while flare 1 seems to be well fit with only a thermal spectrum.



Conclusions & Discussion

The microflares presented in this work can be interpreted as small flares: They occur in active regions, show non-thermal heat input as well as thermal heating. The main differences is that observed slopes of the non-thermal power law spectra are steep with values between -5 to -8 whereas the spectra in normal flares are generally harder. These results are generally robust with respect to background substraction while the thermal fit is much more sensitive and the given temperatures and emission measures are therefore prelimary. The non-thermal emission is observed to extend down to ~7 keV, in some microflares possibly below. Knowledge of this cutoff E0 is crucial to deriving the energy loss rate P of electrons since $P \sim E_0^{-(\gamma-1)}$ where γ is the power law exponent. In earlier work the cutoff was often set to 25 keV (e.g. Crosby, Aschwanden, Dennis, 1993). For the microflares present in this work, the use of 10 keV instead of 25 keV instead a factor of ~500, since the spectra are so steep. This could possibly change the flare frequency distribution published by Crosby, Aschwanden, and Dennis (1993) and lead to a re-evaluation of microflare contribution to coronal heating.

The derived total energies for the microflares discussed are between 10^{26} to 10^{27} erg. This agrees with a rough estimate of the total thermal content.

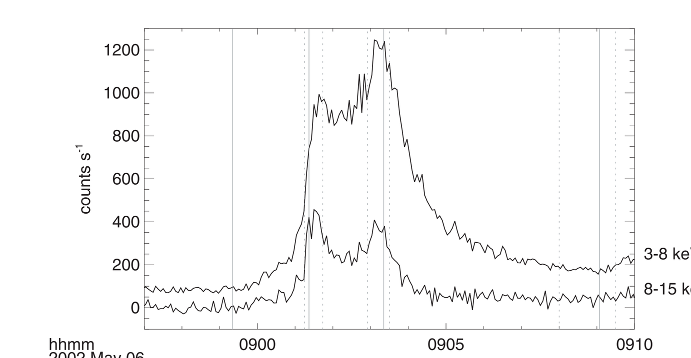
To place these HXR microflares in the context of lower temperature flare emission, a microflare occurring on May 6, 2002, 09:01UT which is comparable to the largest flare occurring in the May 2 time interval (GOES A8 level), is presented here.

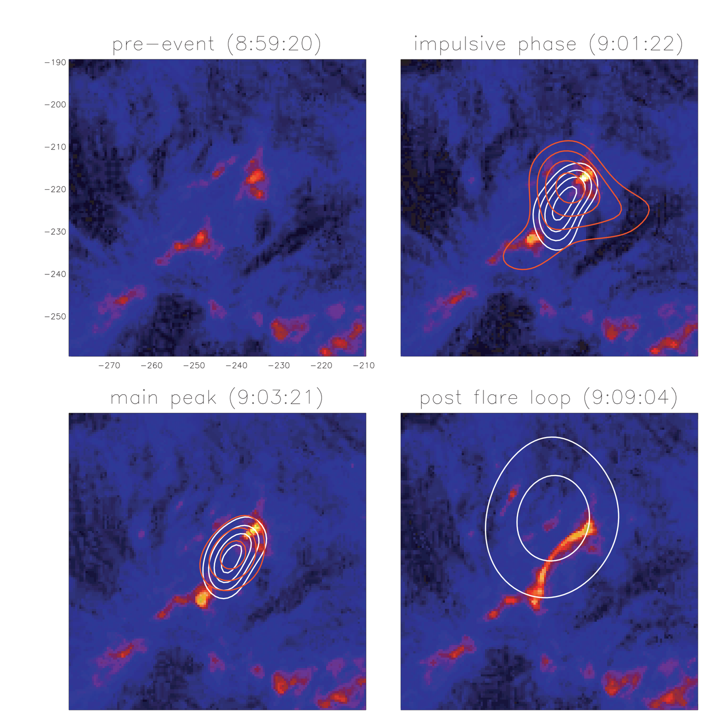
In EUV (195 A), this event shows two bright spots flaring that are already visible in the preflare image. These sources show a very similar time profile as in X-rays; with two peaks as well.

The X-ray emission below 8 keV occurs between the two EUV spots, suggesting a hot loop in between. Above 8 keV, the X-ray image looks different with a strong source near the western EUV spot and a possible weaker source possibly related to the eastern EUV spot.

The image above 8 keV is reconstructed with relatively low statistics and therefore of lower quality.

The rise phase of this microflare can be interpreted as a single loop brightening with footpoints seen above 8 keV and the loop top seen at lower energies.





During the main peak of the event, the emission below and above 8 keV comes only from the loop. About 8 minutes after the rise phase, a very fine and slightly curved loop is seen with TRACE connecting the earlier flaring footpoints.

This is similar to what is observed with RHESSI in large flares.