Non-thermal distributions in RHESSI and RESIK spectra

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Abstract

The contribution present results of joint analysis of RHESSI continuum and RESIK line flare spectra. We show that RHESSI non-thermal component (> 20 keV) associated with the electron beam is well correlated with presence of non-thermal n-distribution of plasma electrons obtained from the RESIK spectra at ~ 2 keV. In addition, such an n-distribution occurs during radio bursts observed in the 0.61 - 15.4 GHz range. Data also suggest that the n-distribution could also explain RHESSI emission below ~ 5 keV. Finally, on the basis of spectral line analysis we argue that the n-distribution does not occupy the same location as the thermal component detected by RHESSI at ~ 10 keV.

Data Analysis

RESIK

In the soft X-ray range, $\sim$ 2 keV, Si lines observed by RESIK[3] are analysed assuming a so-called *n-distribution* of the plasma electrons

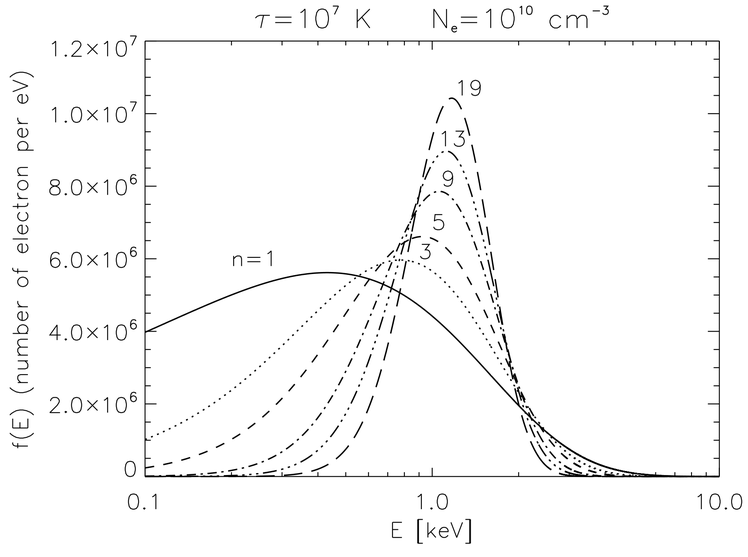
$$f_n(E) \approx E^{n/2}(kT)^{-(n/2+1)} \exp(-E/kT) \qquad \tau = (n+2)T/3\,,$$

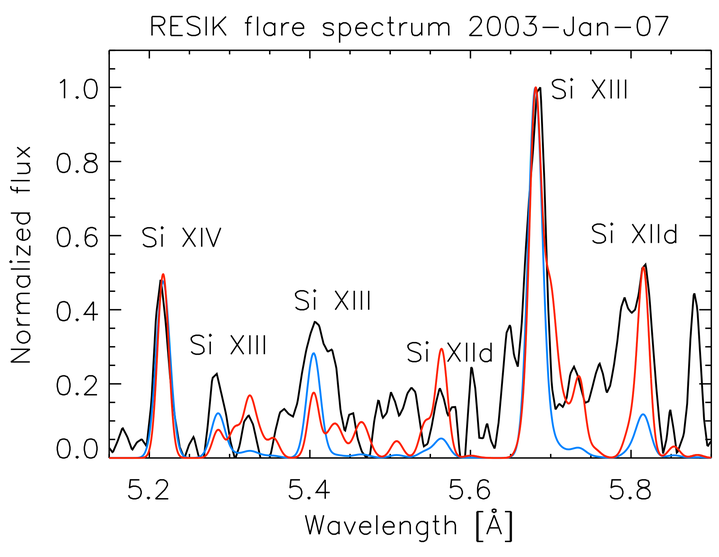
which has enhanced and narrower peak than Maxwell distribution for high n, see Fig. 1, left. Diagnostics of the n-distribution is based on line ratios[1] of two allowed lines SiXIII and SiXIV and a satellite line SiXIId, see Fig. 1, centre and right.

RHESSI

In hard X-rays we use RHESSI[2] data and assume emission is composed of continuum emission (proton-electron bremsstrahlung) plus contribution of Fe (~ 7 keV) and Fe-Ni (~ 8 keV) line complexes. Above ~ 6 keV RHESSI spectra were forward-fittted with an iso-thermal component and a thick-target non-thermal emission of a power-law electron beam.

The n-distribution should also contribute to the bremsstrahlung emission. When the data allowed it, we explored lowest RHESSI energies, from 4 keV, and included thin-target n-distribution emission into the fit.





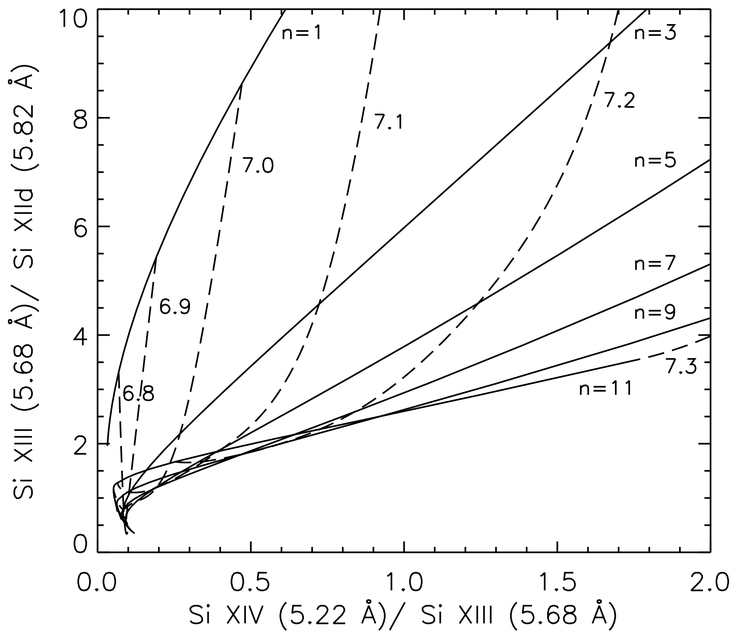


Figure 1: Left: n-distributions, Centre: example of RESIK spectrum together with synthetic spectrum corresponding to n-distribution and Maxwell distribution. ~~Left:~~ synthetic line ratios as functions of n (—) and τ (- - -).

[1] Dzifčáková, E. et al. :2008, A&A, 488, 311 [2] Lin, R. P. et al.:2002, Sol. Phys., 210, 3 [3] Sylwester, J. et al.: 2005, Sol. Phys., 226, 45

Results

- presence of the power-law component in the RHESSI spectra is well correlated with non-thermal n-distribution $n \geq 5$ obtained from RESIK - see Fig. 2

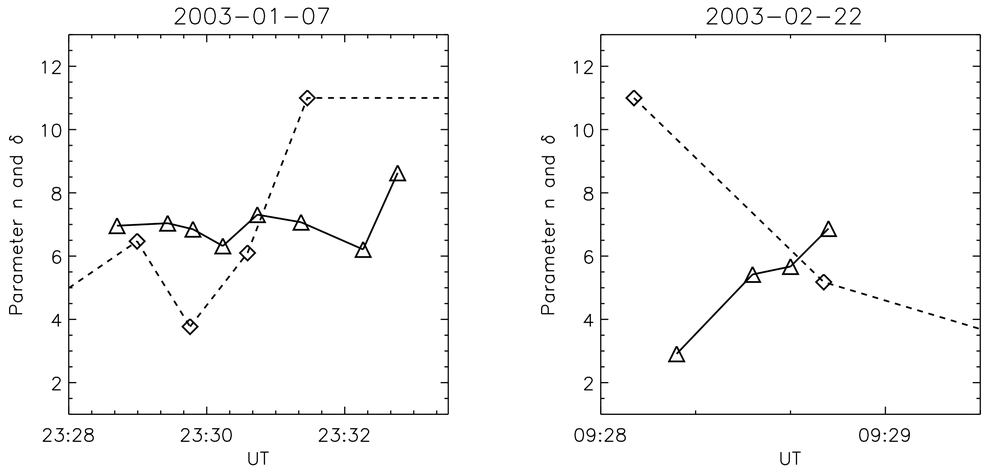


Figure 2: Examples of time evolutions of n (- - -) obtained from RESIK and δ (—) of RHESSI power-law component for two flares (7-Jan-2003, 22-Feb-2003).

- n-distribution of $n \geq 5$ occurs during radio bursts in the 0.61 – 15.4 GHz range - see Fig. 4

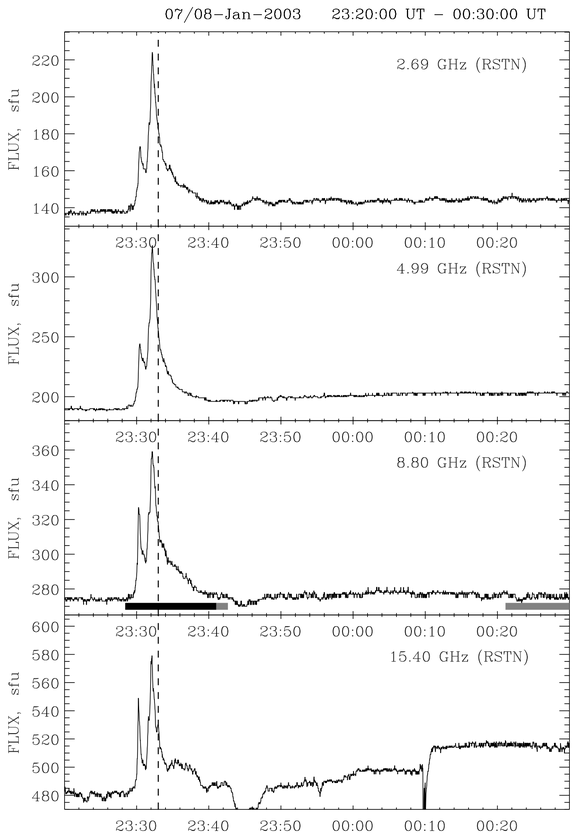


Figure 4: Example of correlation of radio emission and non-thermal n-distribution for the 7-Jan-2003 flare. Heavy thick line denotes times of $n \geq 5$, gray line denotes times of $n < 5$ as obtained from RESIK.

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- RHESSI spectral fits from 4 keV require an additional component consistent with the n-distribution obtained from RESIK - see Fig. 3

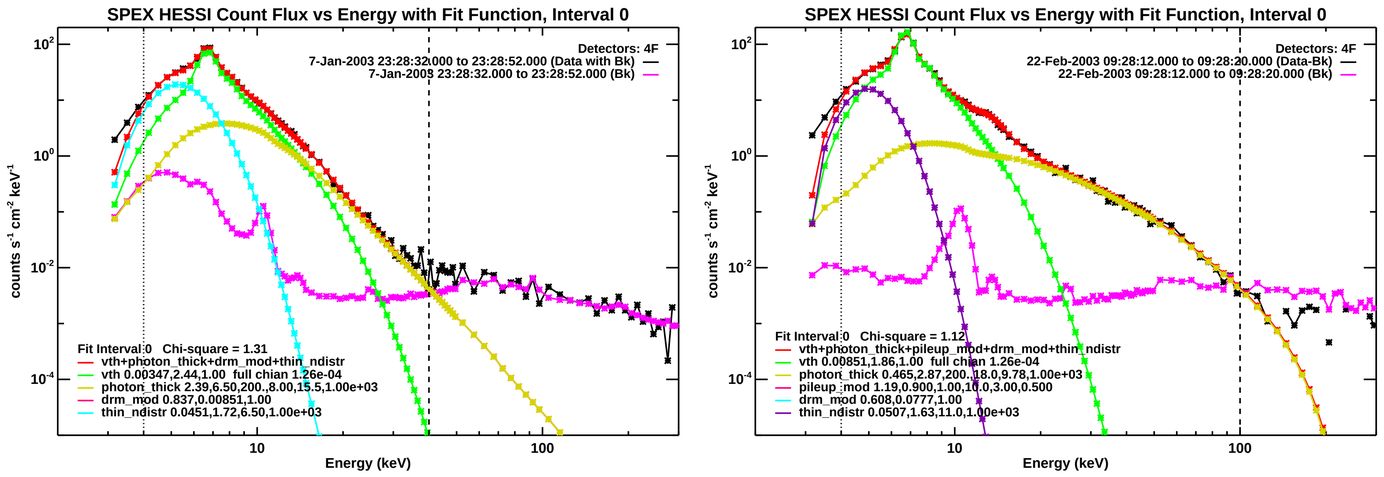

Figure 3: RHESSI spectral fits of two flares (7-Jan-2003, 22-Feb-2003) composed of the n-distribution (—, —), iso-termal, and power-law component.

- due to sensitivity of the Si XIId line to the distribution shape around ~ 2 keV, see Fig. 5 left, emission related to the n-distribution plasma comes from a different substructure than the iso-thermal emission, although RHESSI corresponding sources (3 – 6 keV and 6 – 12 keV) are almost co-spatial (Fig. 5, right)

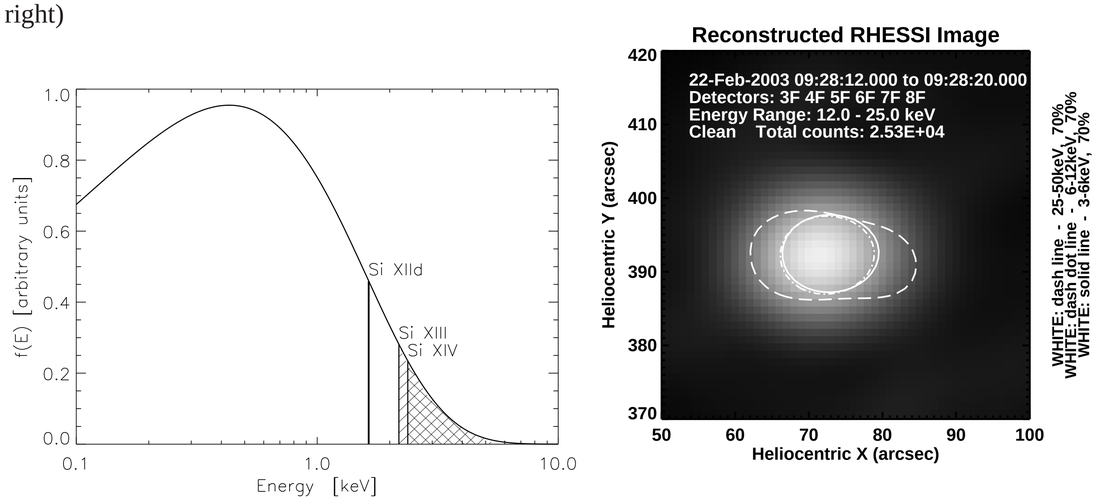

Figure 5: Left: schematic figure indicating which parts of a distribution influence intensities of Si lines used in the RESIK diagnostics, Right: RHESSI image of the 22-Feb-2003 flare.

Conclusions

Two independent methods and data sets indicate a non-thermal electron distribution in the 2 – 5 keV range. RESIK data suggest that n-distribution plasma does not occupy the same structure as the thermal plasma. For the first time the RHESSI excess emission below ~ 5 keV is fitted and explained as due to the n-distribution. RHESSI and RESIK n-distribution parameters agree within uncertainties:

22-Feb-2003: $n_{\mathrm{RHESSI}} = 2 - 9\ (\geq 4.5)_{\mathrm{RESIK}}$ $k\tau_{\mathrm{RHESSI}} = 1.0 - 1.5$ keV $(1.16 - 1.57)_{\mathrm{RESIK}}$

07-Jan-2003: $n_{\mathrm{RHESSI}} \geq 5\ (\geq 3.3)_{\mathrm{RESIK}}$ $k\tau_{\mathrm{RHESSI}} = 1.5 - 2.6$ keV $(0.94 - 1.46)_{\mathrm{RESIK}}$

For more details see Kulinová, A. et al.: 2011, A&A, submitted.