# Application of kappa distribution to RHESSI flare spectra

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# $\kappa$ DISTRIBUTION

In situ detection - solar wind, Earth's bow shock

- energetic tails of detected electrons are often modelled by $\kappa$ distribution

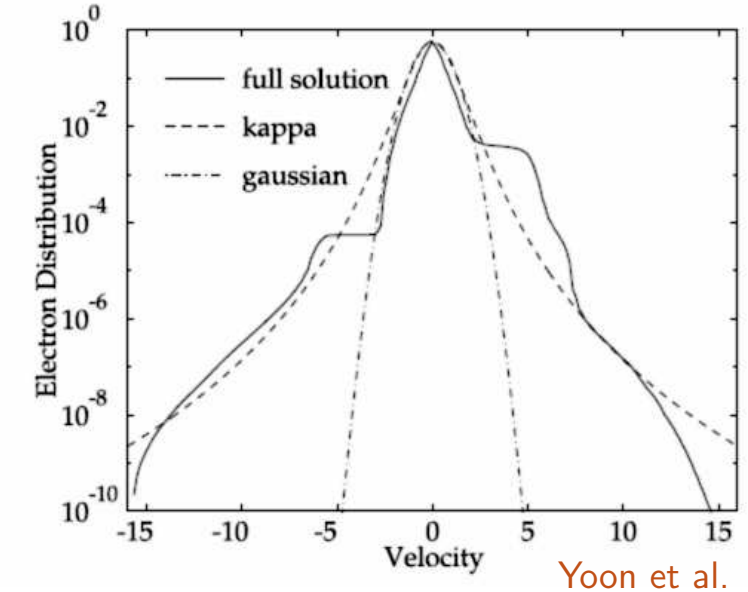
Numerical simulations

- self-consistent acceleration by weak turbulence and beam-plasma interaction (Yoon et al, 2006; Rhee et al, 2006)

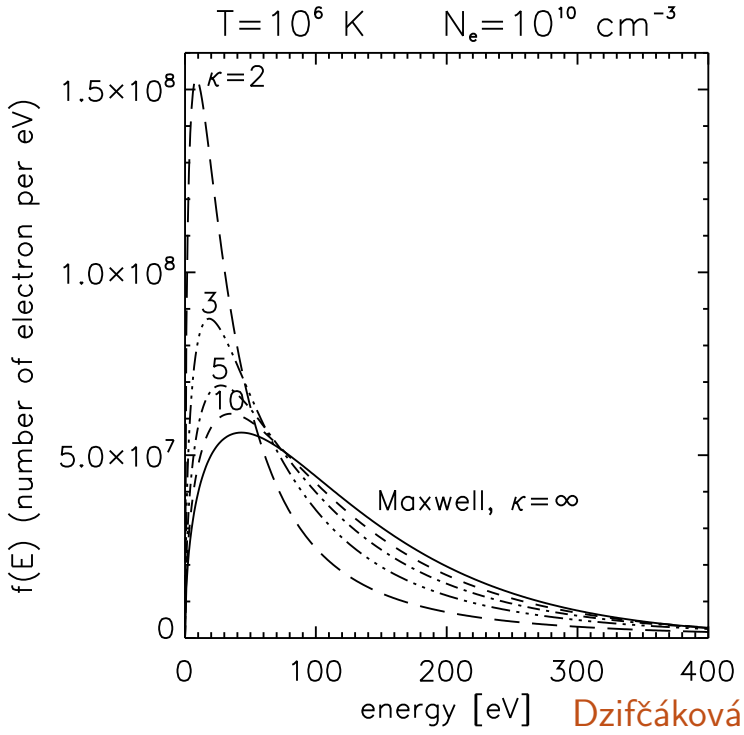
Properties of $\kappa$ distribution

$$f_\kappa(E) = A_\kappa \frac{2\sqrt{E}}{\sqrt{\pi(kT)^3}} \left(1 + \frac{E}{(\kappa - 1.5)kT}\right)^{-(\kappa+1)}$$

- close to Maxwellian for $\kappa \to \infty$
- same mean energy as Maxwellian
- no low-energy cutoff




Yoon et al. (2006)

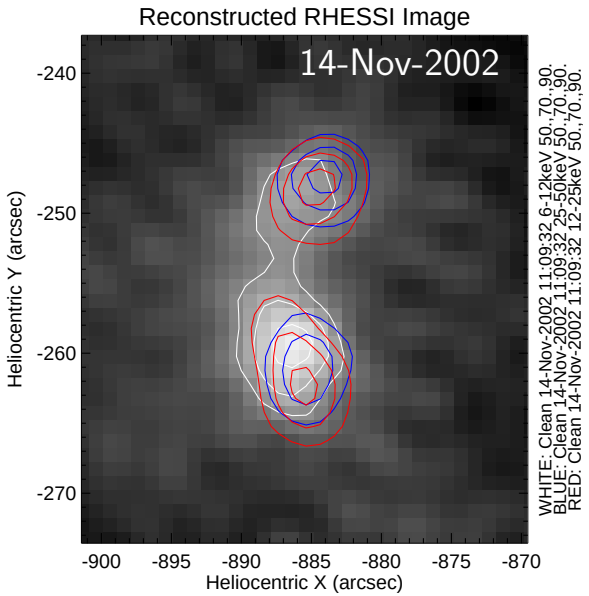


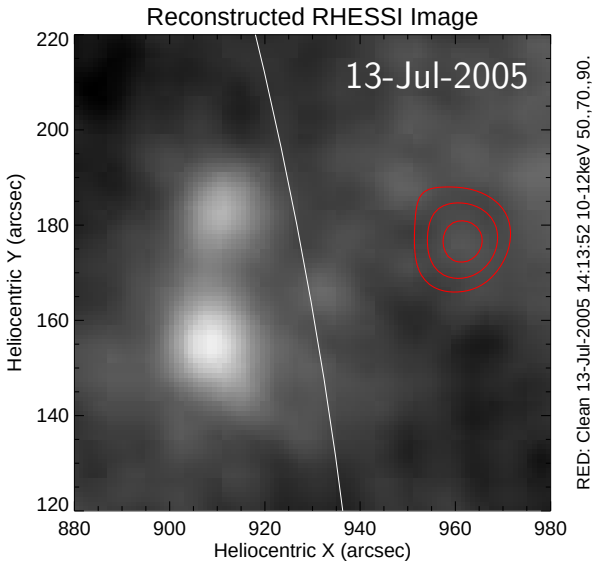

Dzifčáková (1992)

# Fitting RHESSI spectra

## Are spatially or feature integrated spectra consistent with $\kappa$ distribution?

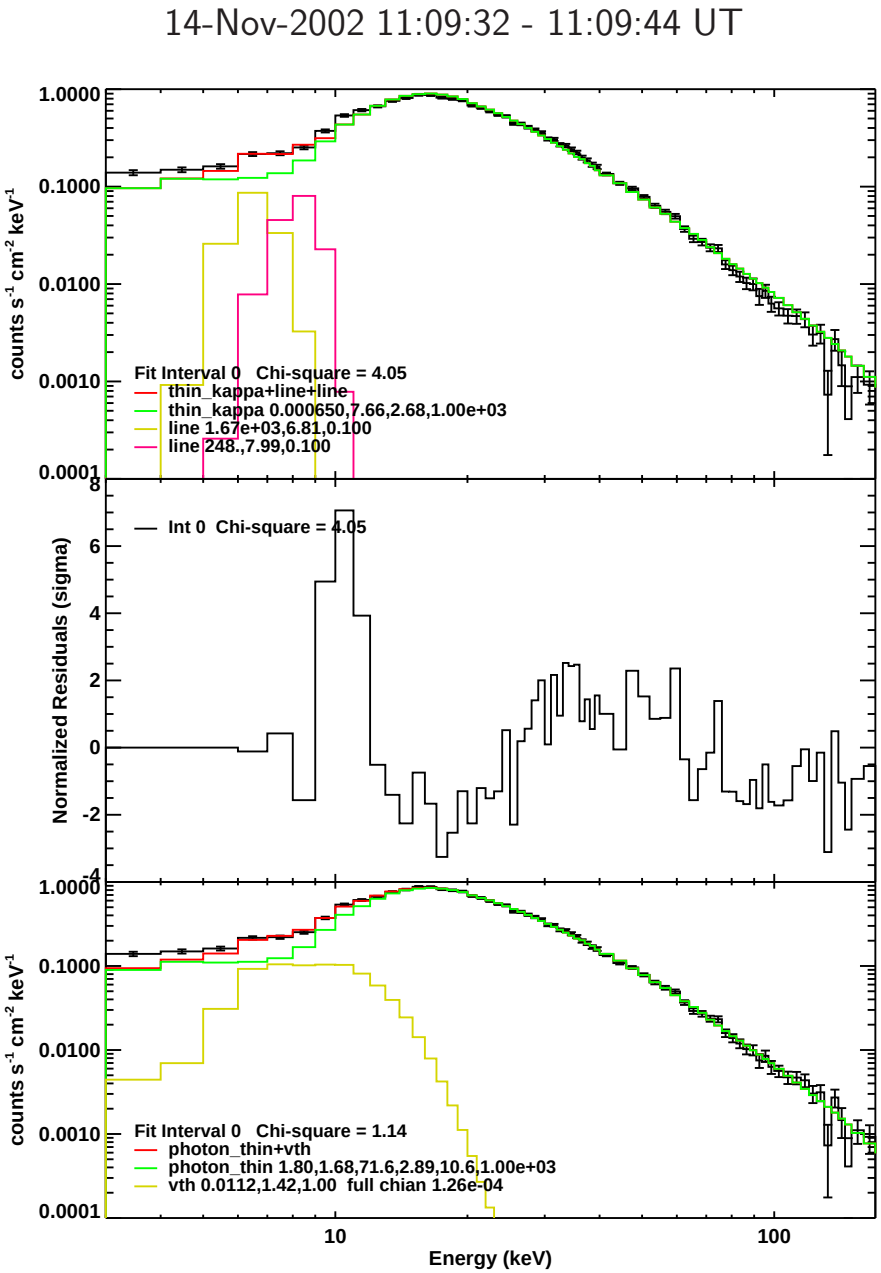
- several flares were selected:
  - weak thermal component, "non-thermal" emission down to 6 keV (C5.5)
  - significant thermal component (M5.1)
  - well separated sources
  - partially occulted flares
- forward fit using
  - vth plus thin target emission of a power-law $\overline{F}(E)$
  - $\kappa$ plus 2 lines at 6.7 and 8 keV
  - fit parameters for $\kappa$: $\kappa$ index, $T$, $\overline{n}V\overline{N}_\kappa$, (high-energy cutoff)



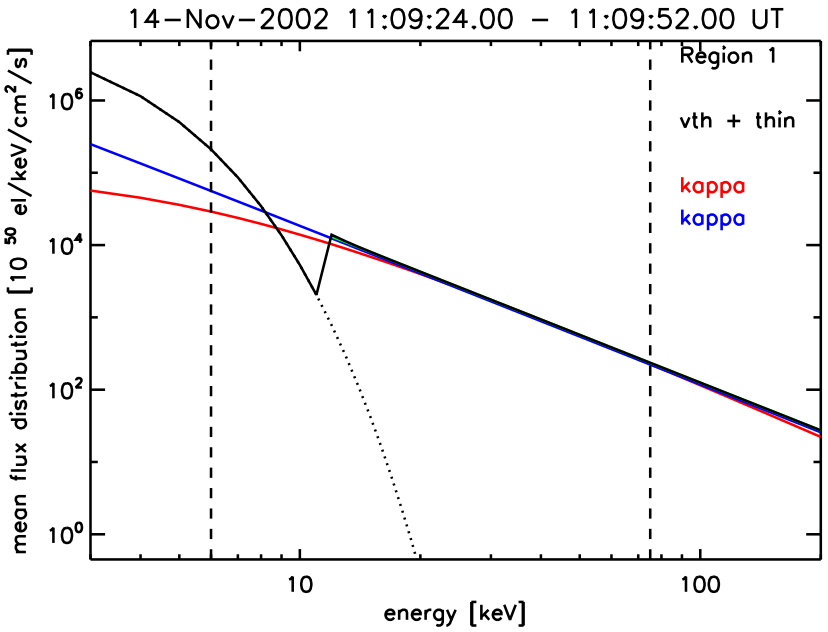
# Spatially integrated spectra - disc events

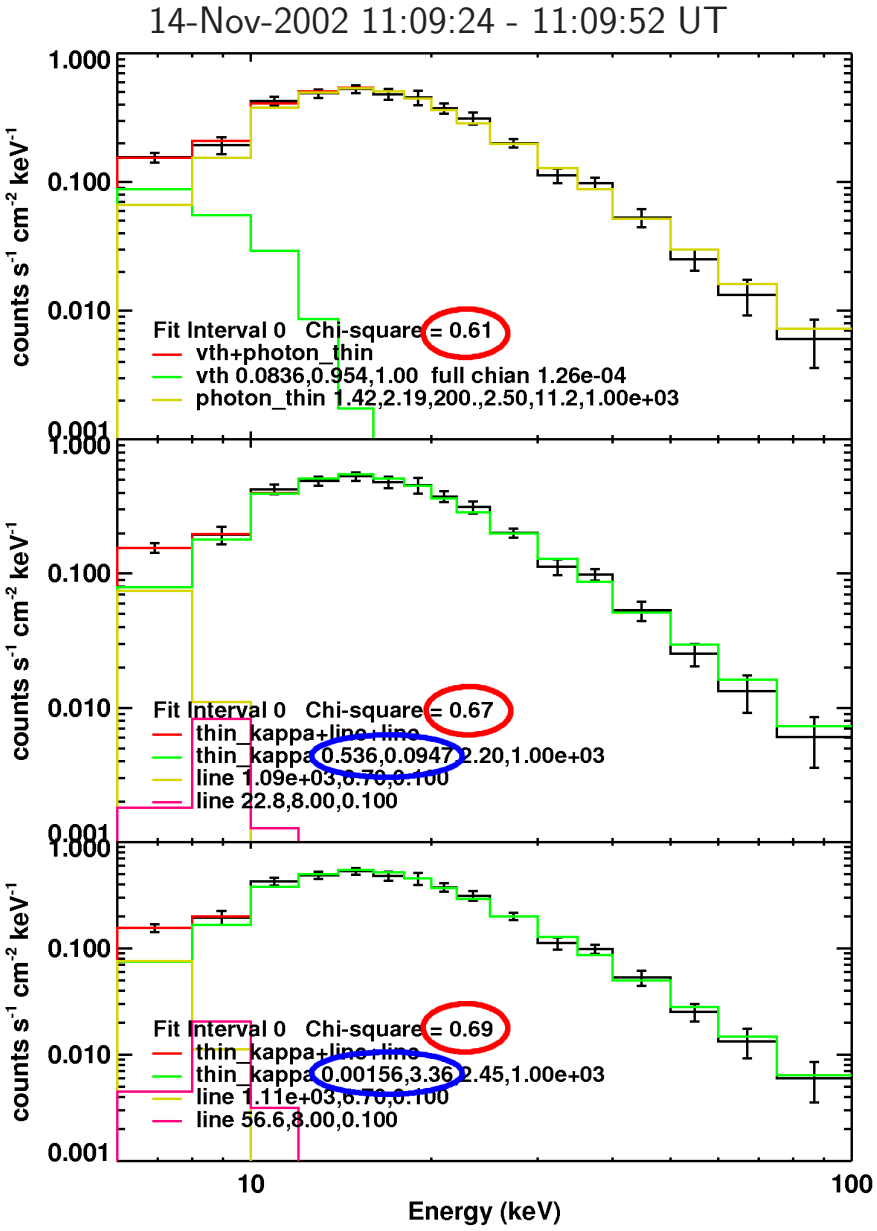
- no satisfactory fit using $\kappa$
  - generally large residua at $\sim$10 keV
  - $\kappa$ index describes well high energy part
- good fit with "vth+thin"
  - generally better than "$\kappa$ + lines"
  - no high residua
- combination of several sources with distinct plasma parameters (footpoints, thermal source) difficult to fit by one $\kappa$ distribution



# Imaging spectroscopy - footpoints

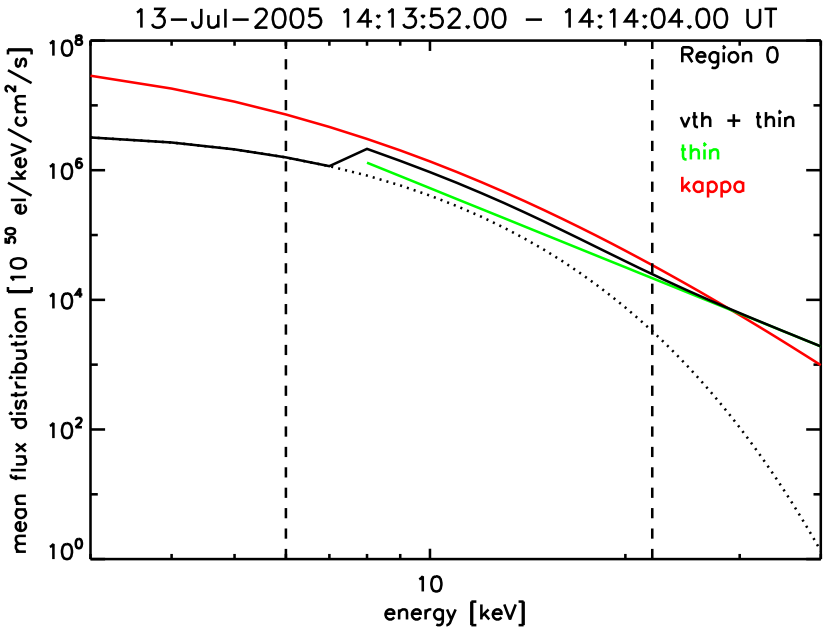
- good fits both by "$\kappa$ + lines" and "vth+thin"
- $T$ and $\overline{n}V\overline{N}_\kappa$ are not constrained
  - equally good fits with different values !
- consistent electron distributions in $E \geq 10$ keV
  - lower energies given by $T$, $\overline{n}V\overline{N}_\kappa$

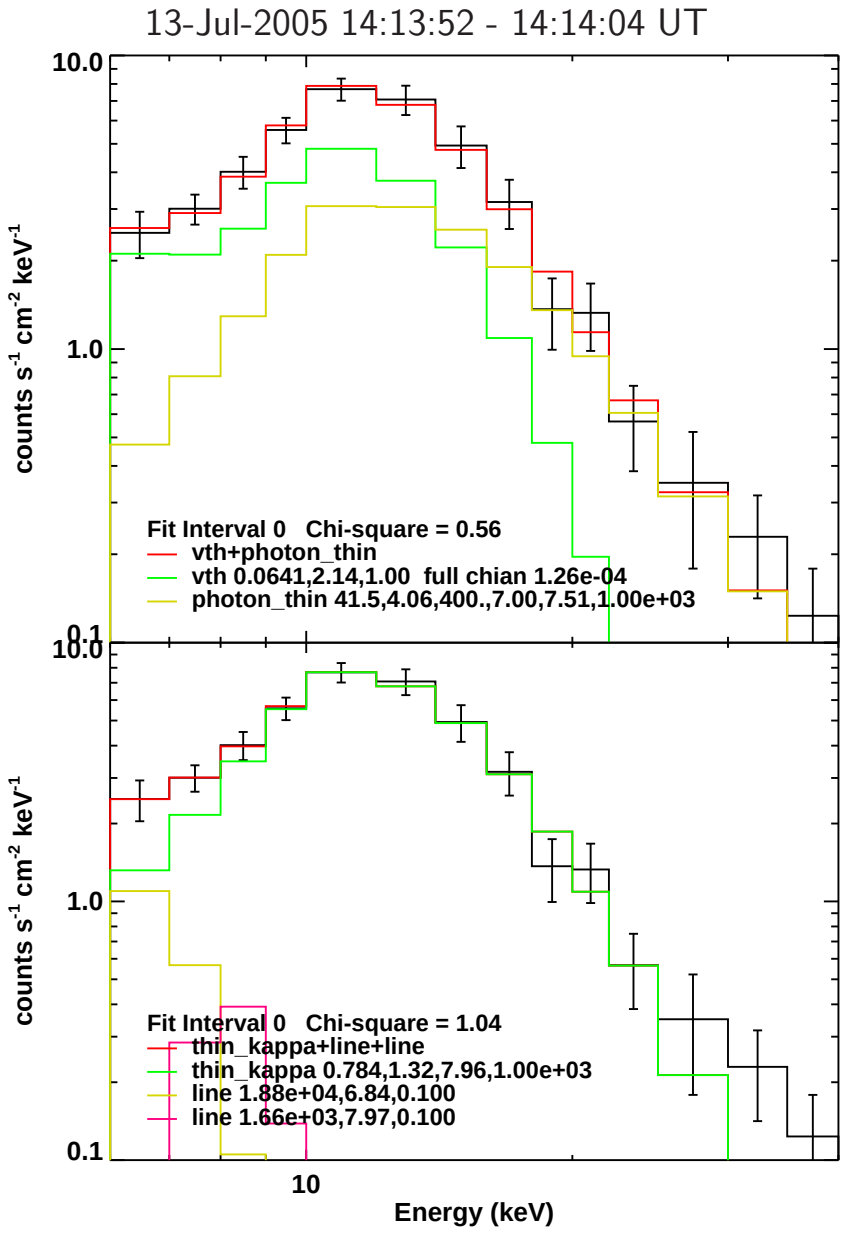


# Imaging spectroscopy - coronal source

- good fits both by "$\kappa$ + lines" and "vth+thin"
- similar electron distributions in $E \geq 8$ keV
  - consistent with X-ray spectrum without need for a low-energy cutoff
  - larger differences at lower $E$



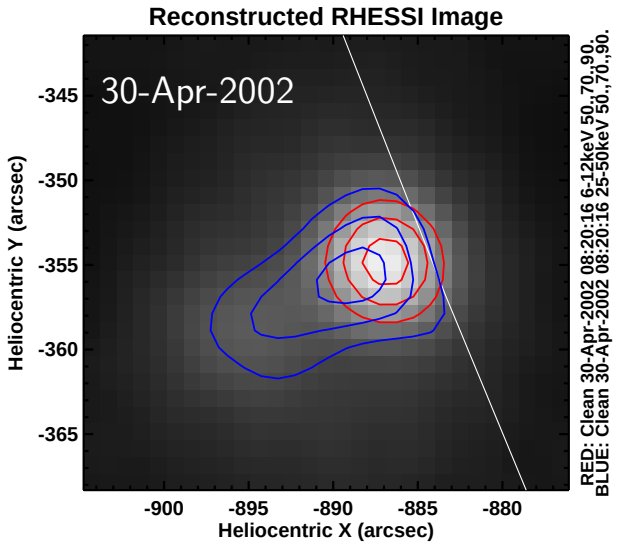



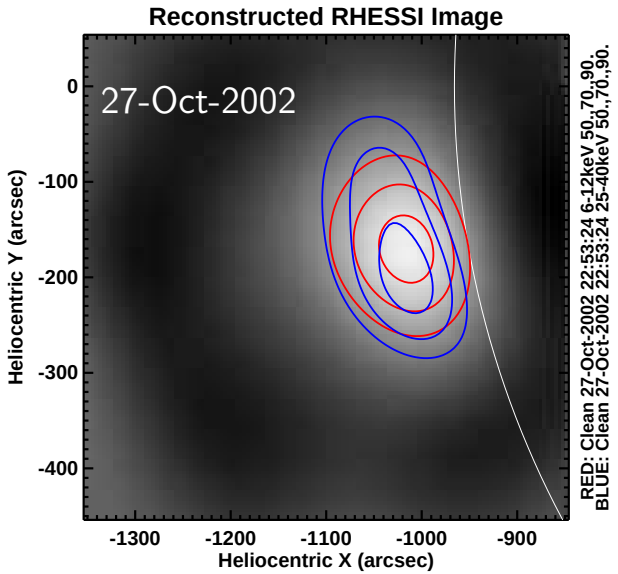
# Spatially integrated spectra - occulted flares

- RHESSI "sees" only coronal source
- footpoint emission is behind the limb

⇓

- high-resolution spectra of the coronal source to 50 keV
- events of cospatial soft and hard X-ray sources selected
  - model assumes beam injection into uniform isotermal plasma



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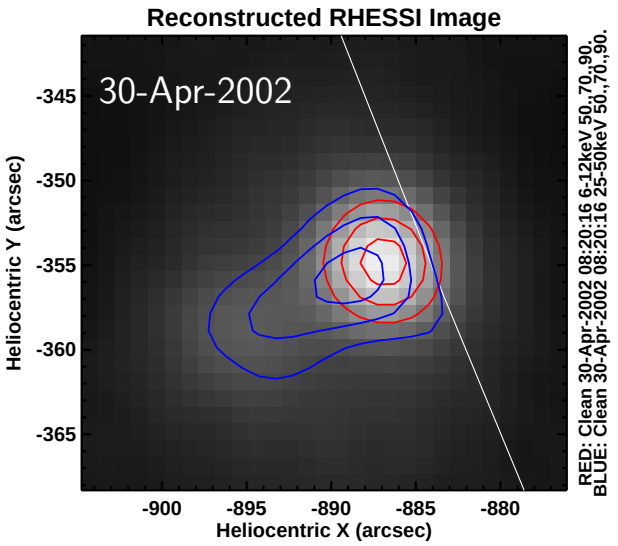
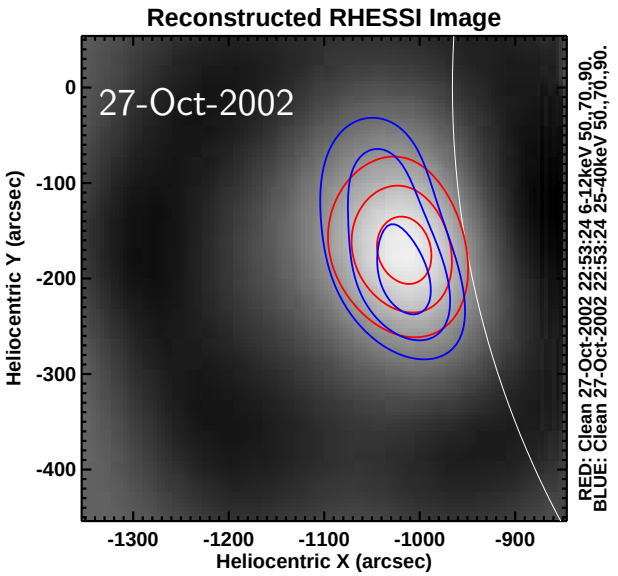
30-Apr-2002

- nearly cospatial 6-12 keV and 25-50 keV emission
- large residua for $\kappa$, good fit for "vth+thin"



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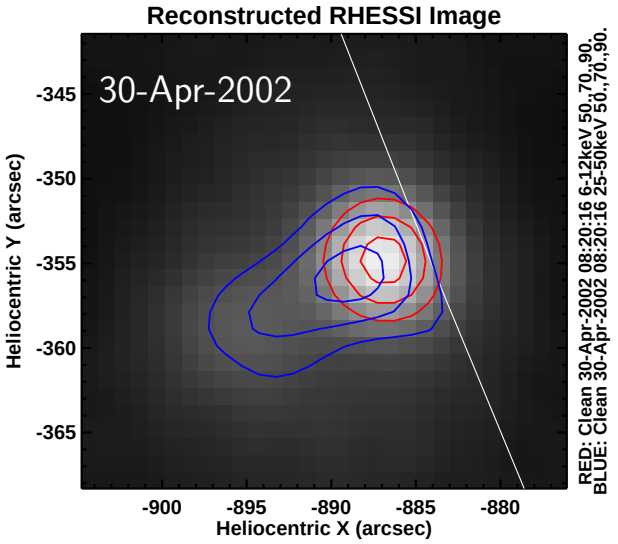
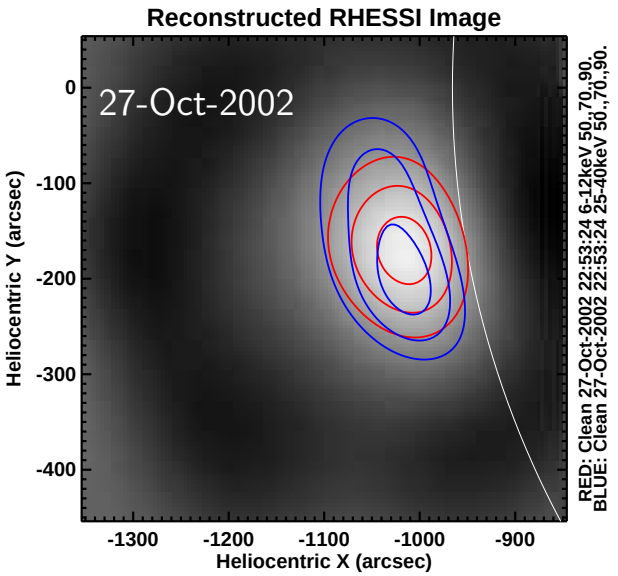
27-Oct-2002

- $\gamma$-ray event detected at Mars, extended coronal source (200 arcsec)
- good fits using $\kappa$ as well as "vth+thin"



# Conclusions

- spatially integrated spectra of disc flares are not consistent with single $\kappa$ distribution
- footpoint X-ray emission can be fitted by $\kappa$ distribution but $T$ and $\overline{n}V\overline{N}_{\kappa}$ are not constrained
- $\kappa$ distribution of electrons can describe X-ray emission of some coronal sources
  - numerical simulations assume only wave-particle interactions in plasma, possibly appropriate for coronal sources but not for footpoints where Coulomb collisions could be dominant

## Next steps

- electron maps of coronal sources and partially occulted flares
- analysis of soft X-ray emission
  - 6.7 and 8 keV lines, RESIK, SphinX