Cool Stars 17 splinter session

Non-thermal processes in coronae and beyond

June 26th 2012 Barcelona, Spain

Hard X-ray emission from the solar corona detected with the SphinX spectrometer

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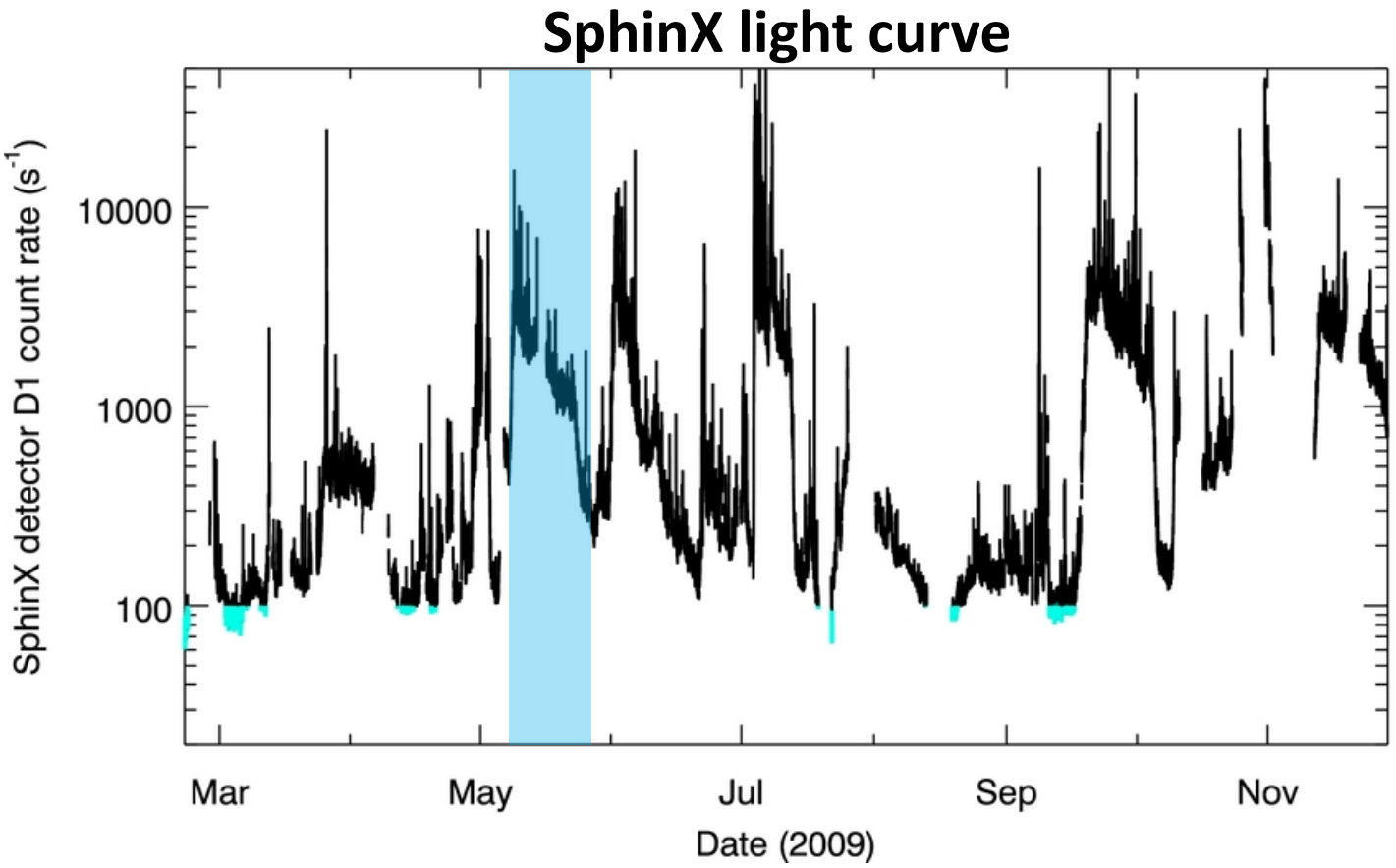
Outline

- Detection of hard X-ray emission from the quiscent corona of the Sun
- Detailed broadband spectral analysis
- Spectral properties of the hard X-ray emission
- Origin of the hard X-rays (thermal vs. non-thermal scenarios)

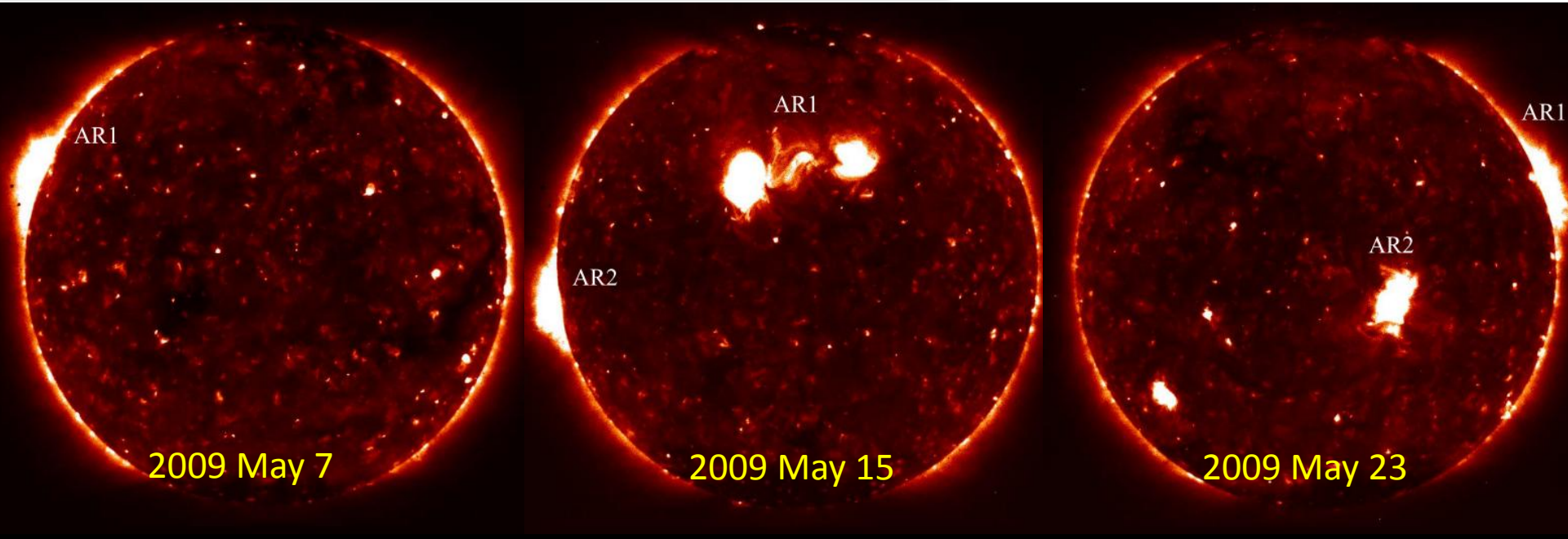
The Data

We analized spectra collected by the Solar Photometer In X-rays, **SphinX** (Sylwester et al. 2008, Gburek et al. 2011) a broadband (1.3-14.9 keV) spectrometer with moderate spectral resolution (~460 eV)



Time window: 7-24 May 2009 (rel. high X-ray flux, no significant flares)

The Data

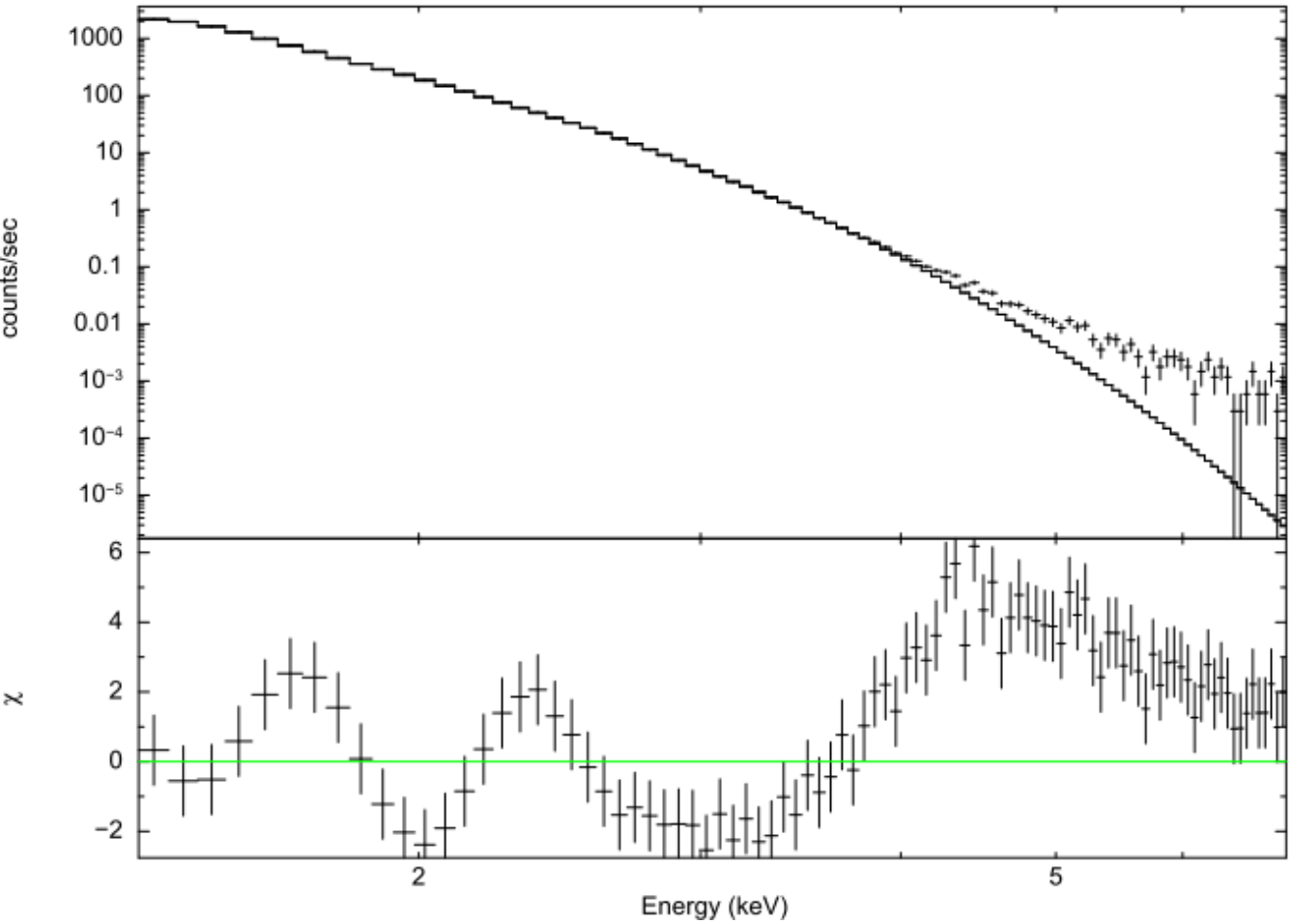


Hinode/XRT synoptic images of the solar corona in the Ti-poly filter

Data reduction:

- Inspection of light curves: removal of a B1.0 and a A5.9 flare
- Data filtering to remove spurious measurements (non-GTI events, particle related events, etc .)
- Filtered data: 3.9 x 10^7 events
- Filtered exposure time: 57 ks

Spectral analysis



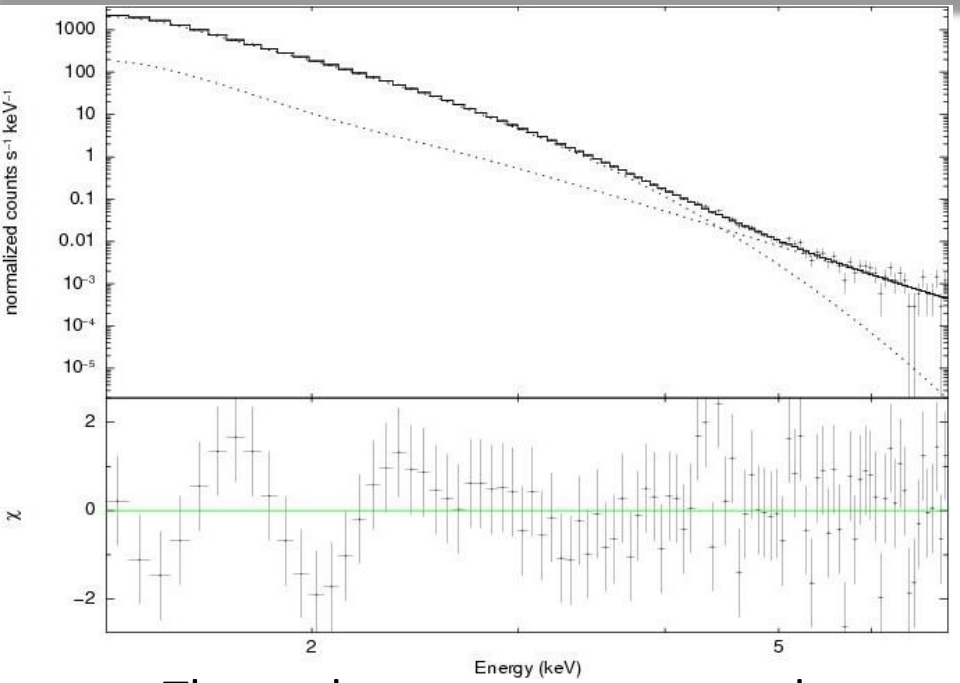
$T=2.83 \times 10^6$ K

$EM=5.36 \times 10^{47}$ cm^{-3}

$\chi^2=657.0$ (93 d. o. f.)

A single thermal component (optically thin isothermal plasma, APEC model in XPEC, based on AtomDB 2.0) **cannot fit** the broadband **solar spectrum**

Hard X-ray emission



Thermal component + powerlaw

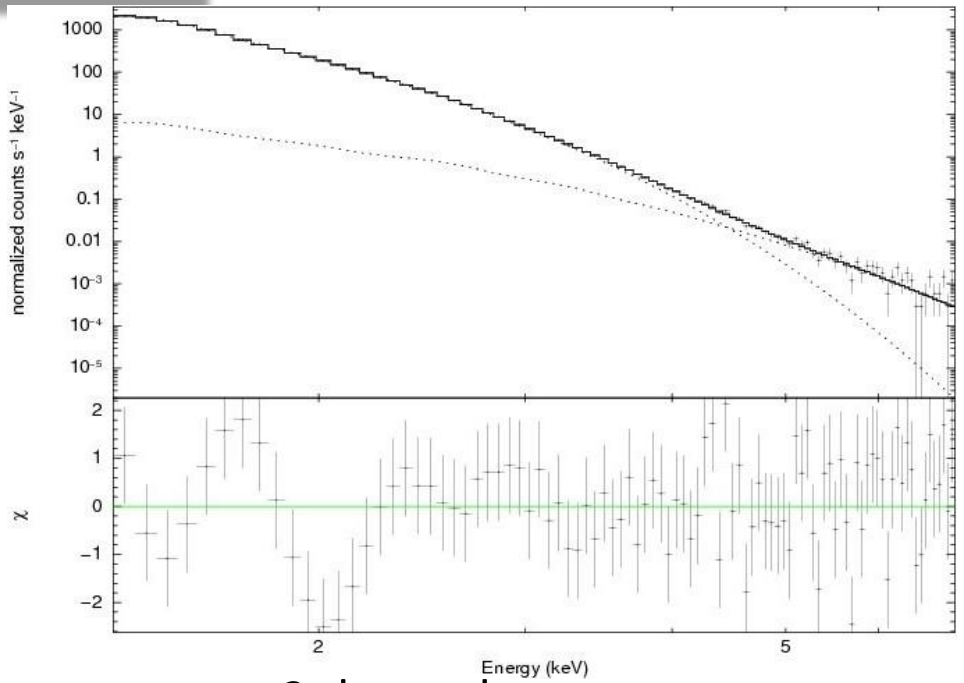
$T = 2.73 \pm 0.01$ (10^6 K)

$EM = 6.3 \pm 0.2$ (10^{47} cm^{-3})

$\gamma = 9.0 \pm 0.3$

$N = 7 \pm 3 \times 10^4$ cm^{-2} keV^{-1} s^{-1})

$\chi^2 = 94.0$ (91 d.o.f.)



2 thermal components

$T_1 = 2.73 \pm 0.01$ (10^6 K)

$EM_1 = 6.3 \pm 0.2$ (10^{47} cm^{-3})

$T_2 = 6.6 \pm 0.3$ (10^6 K)

$EM_2 = 2.7 \pm 0.2$ (10^{44} cm^{-3})

$\chi^2 = 97.1$ (91 d.o.f.)

SphinX spectral resolution do not allow us to discriminate between the two scenarios

Origin of the hard X-ray emission

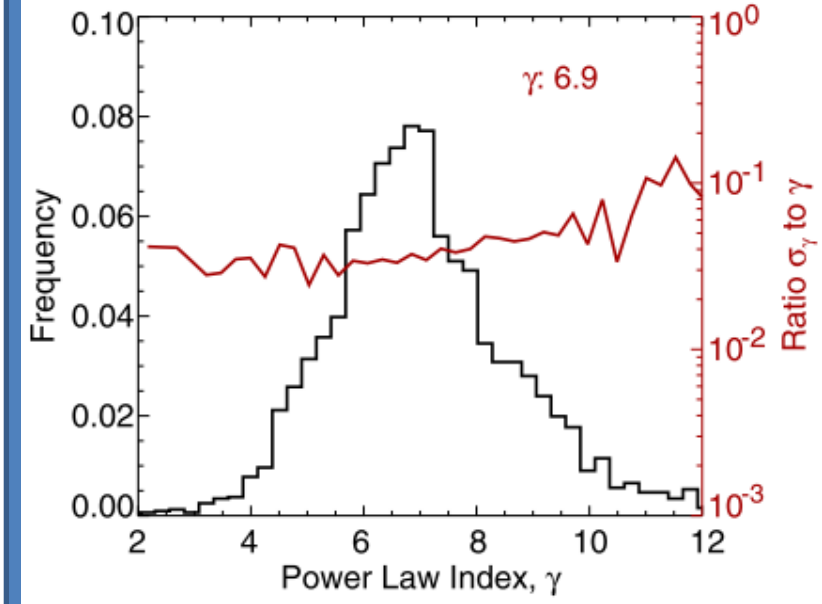
The **hard component** was not detected in the lowest activity periods of the 2009 solar minimim (Sylwester+ 2012) ➡ **link with active regions**

Non-thermal scenario

$\gamma \sim 9$ (thick target bremsstrahlung?) steeper than the average value (γ=6.9) observed in HXR microflares

Thermal scenario

Temperature consistent with that found in active regions (Reale+2009, 2011; McTiernan 2009; Testa&Reale 2012)

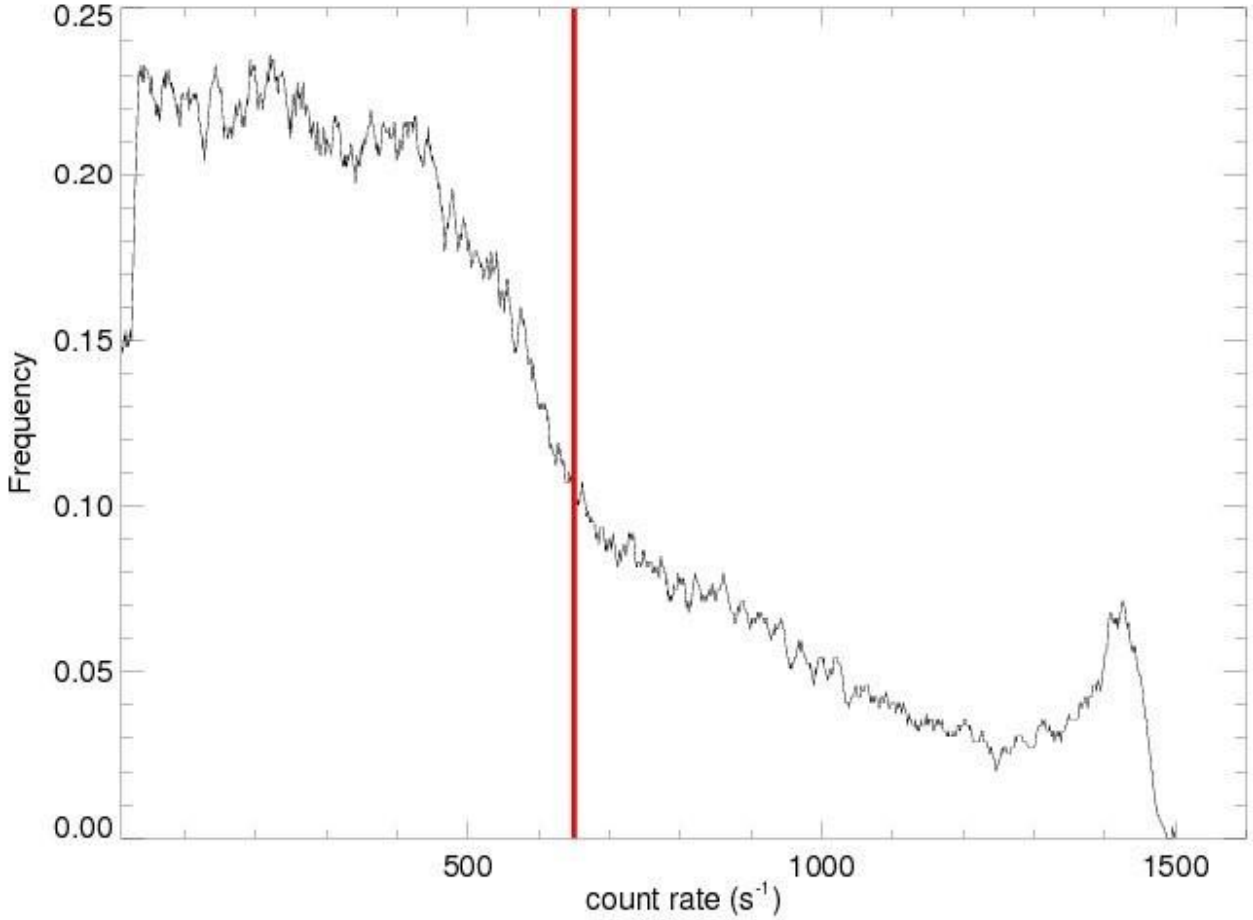


Distribution of the power-law index for RHESSI microflares (Hannah +2008)

A spectral resolution $\Delta E \sim 100$ eV in the 4-7 keV band is necessary to discriminate between the two scenarios

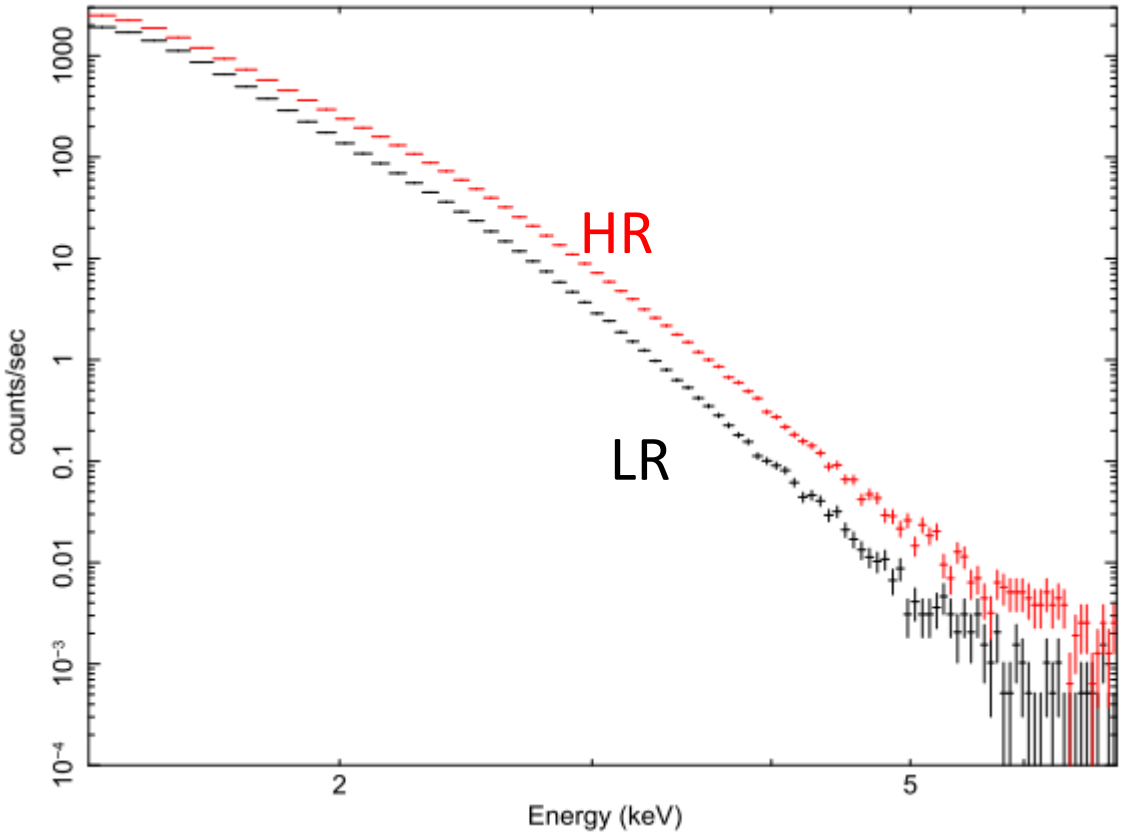
Count-rate resolved spectral analysis

Possible contribution from unresolved microflares: does the hard X-ray emission originate only during high flux periods?



We extracted a spectrum from time bins with count-rate >650 s^{-1} **(HR spectrum)** and from time bins with count-rate <650 s^{-1} **(LR spectrum)**

Count-rate resolved spectral analysis



$T = 3.17 \pm 0.01$ (10^6 K)
$EM = 4.3 \pm 0.1$ (10^{47} cm^{-3})
$\Gamma = 8.2 \pm 0.3$
$N = 5 \pm 2 \times 10^4$ cm^{-2} keV^{-1} s^{-1})
$\chi^2 = 102.7$ (91 d.o.f.)

$T = 2.65 \pm 0.01$ (10^6 K)
$EM = 6.1 \pm 0.2$ (10^{47} cm^{-3})
$\Gamma = 8.9 \pm 0.3$
$N = 4 \pm 2 \times 10^4$ cm^{-2} keV^{-1} s^{-1})
$\chi^2 = 91.9$ (91 d.o.f.)

Both LR HR spectra **cannot be fitted by a single thermal component** (χ^2=332.5 and 488.3, respectively, with 93 d.o.f.), though HR spectrum is harder

Conclusions

- We detected hard X-ray emission in the quiescent solar corona
- The hard component dominates the solar spectrum above 4 keV
- Both thermal and non-thermal model can fit the SphinX spectra
- Hard X-ray emission is present even if microflare contribution is removed
- Our results indicate that a minor flaring activity (nanoflares) is ever present in active regions