RHESSI Microflare Statistics

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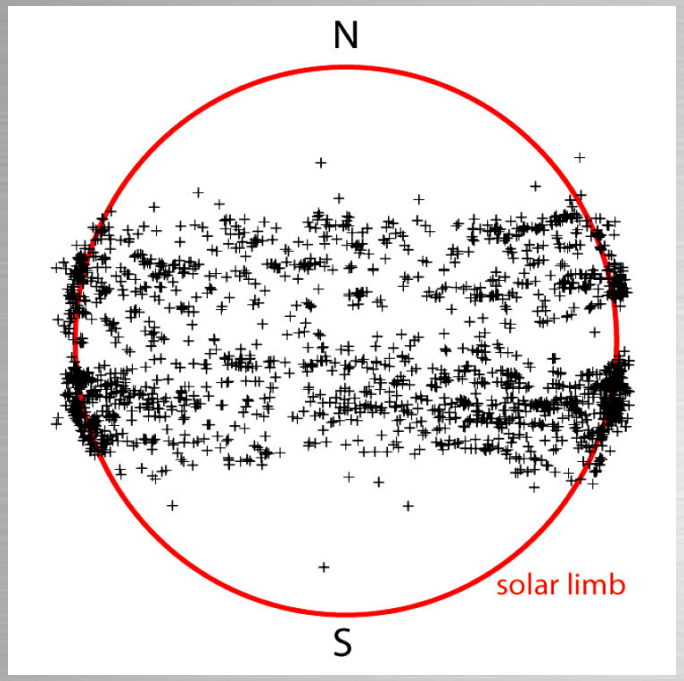
Motivation: Why RHESSI?

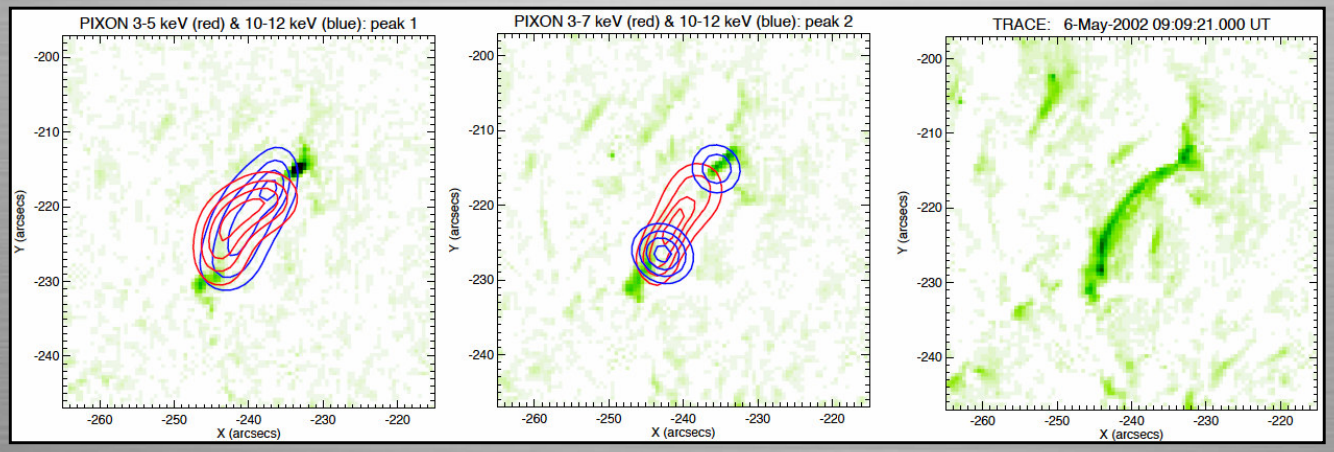
- RHESSI (Reuven Ramaty High Energy Solar Spectroscopic Imager)
  - Provides unique sensitivity in 3-15 keV.
  - Effective area ~100 larger than at 10 keV.
    - HXIS on SMM
  - Energy resolution of 1 keV.
- RHESSI can provide new information on low-level energy releases:
  - X-Ray Bremsstrahlung from heated and accelerated electrons in microflares
- See lots of small bursts of x-rays
  - signatures of energy release into the corona.
  - but how much and how often?

RHESSI Microflares



Rauscher et al.

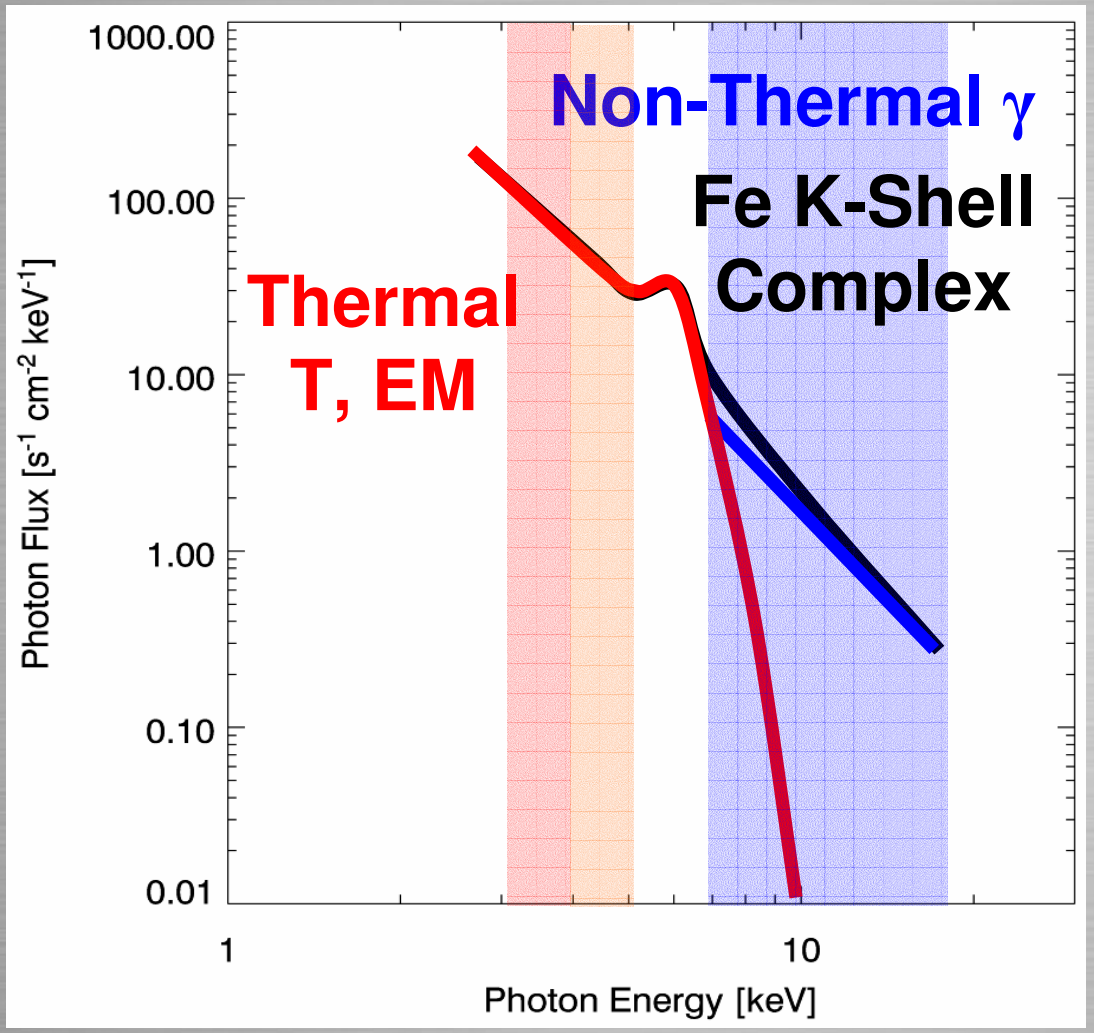
- These are small flares (A-C Class), occurring in active regions
  - coronal acceleration (reconnection?)
  - heated & accelerated electrons
  - then bremsstrahlung out.
- RHESSI provides the x-ray spectrum and image of these events
  - times of shutter out and no decimation (quiet times) get about 2.5 flares per hour



Looks like non-thermal footpoints plus lots of information in x-rays before EUV loop

- 10,000s of microflares so far
  - ***so need an automated process to characterise these events***

Spectrum Characterisation



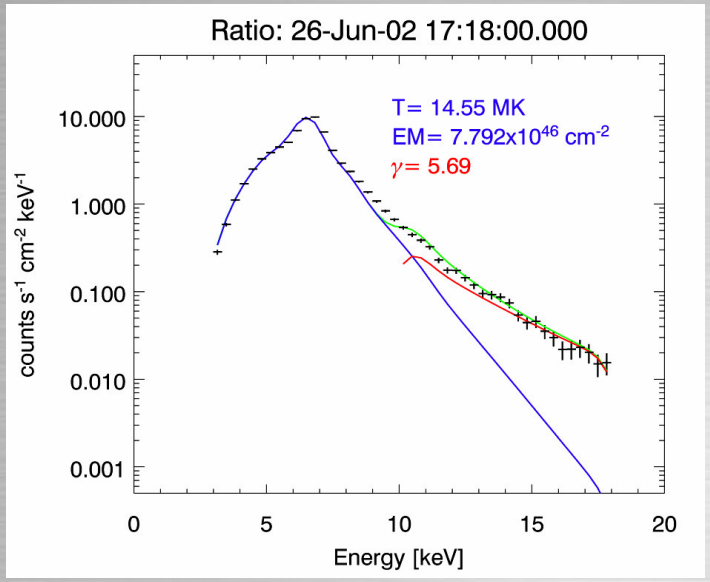
Cartoon photon spectrum

- **Thermal Bremsstrahlung**
  - Temperature **T**
  - Emission Measure **EM=n²V**
- **Non-Thermal**
  - Power-law index γ
- **OSPEX**
  - Sophisticated fitting
  - Tricky Interpretation
  - Does not also work, especially smaller small flare

- **Ratio:** Less Accurate but always gives answer and know its limitations
  - **T** and **EM** from ratio of counts in (3-4.67)/(4.67-5.67) keV
  - Subtract thermal model for **T,EM** from data converted to photon spectru
  - Line Fit whatever is left to give γ

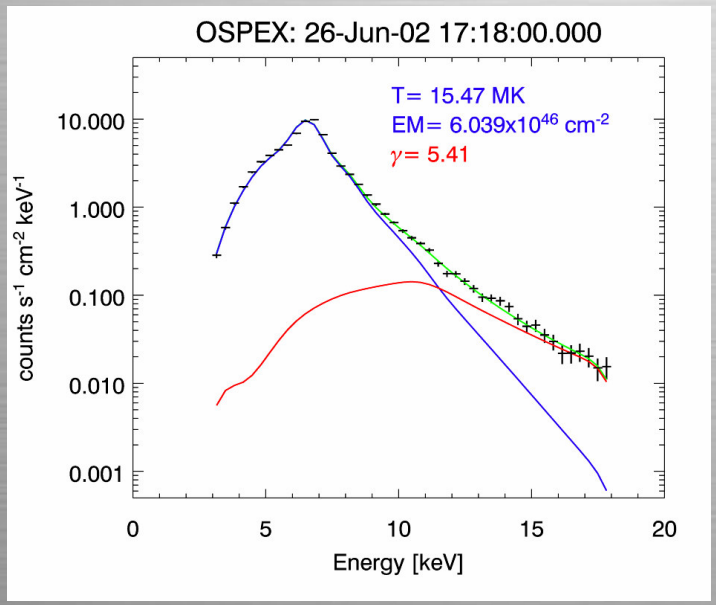
Microflare: 26-06-2002, B1.8

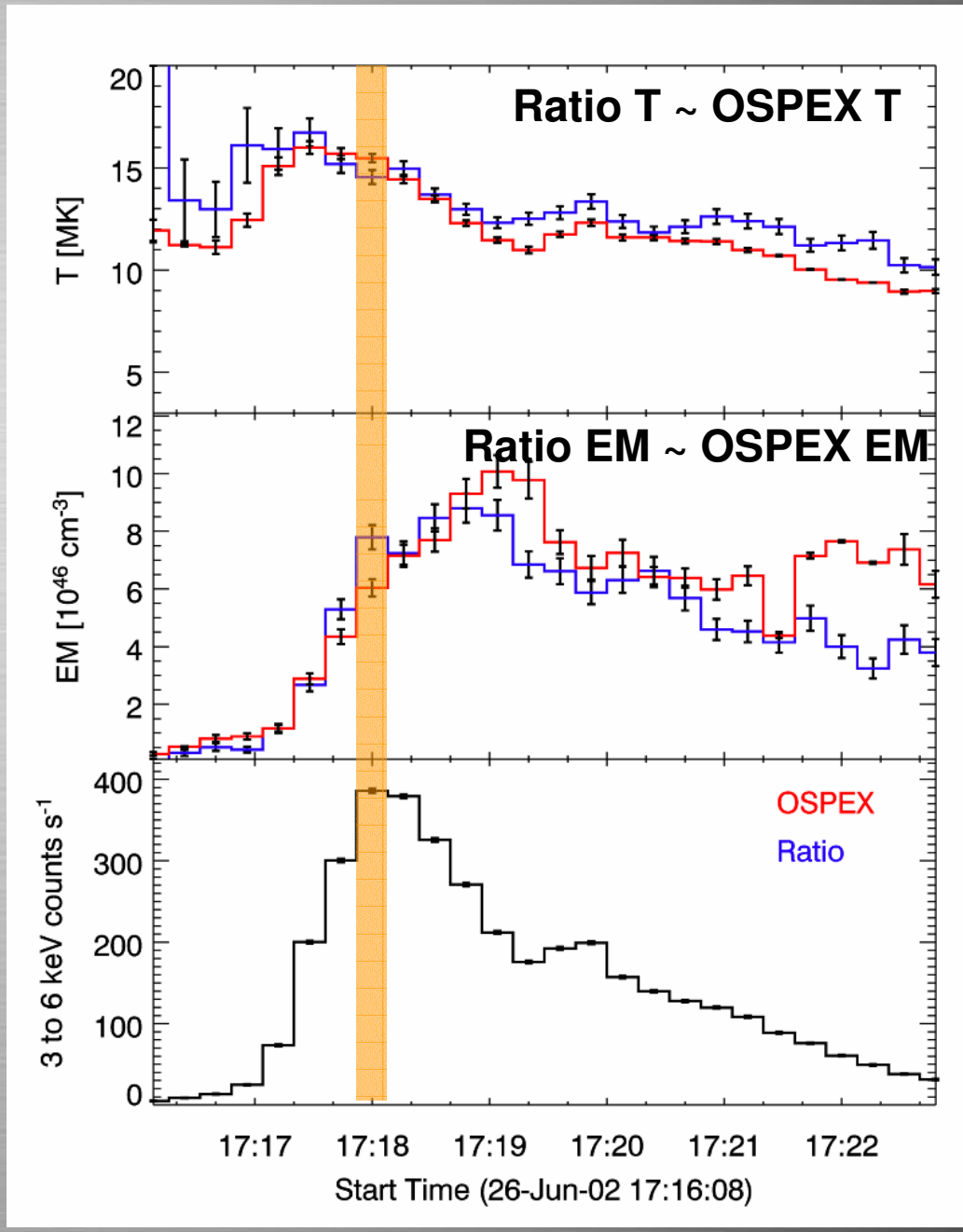
Peak Time



Good Fit and Agreement

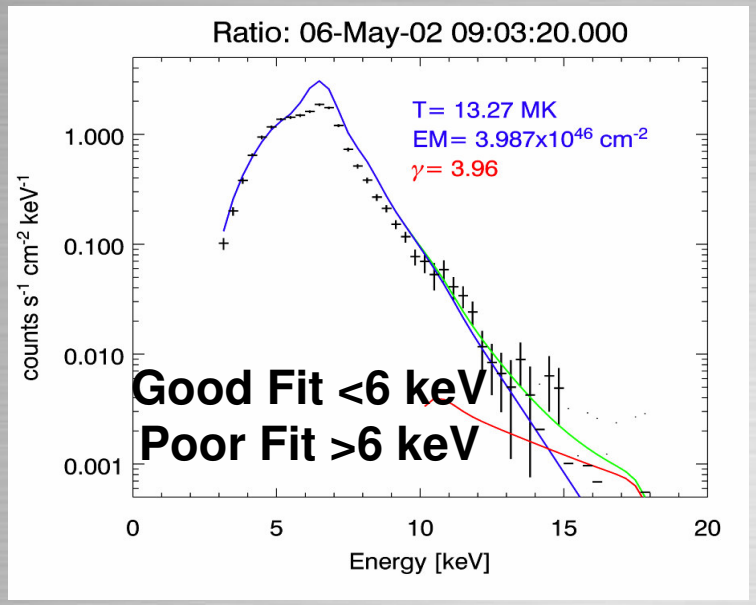
Peak Time





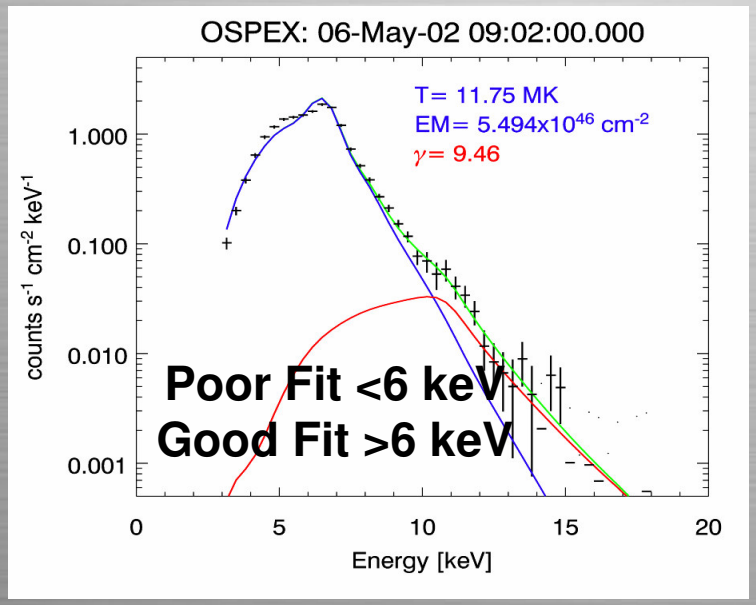
Microflare: 06-05-2002, A7.8

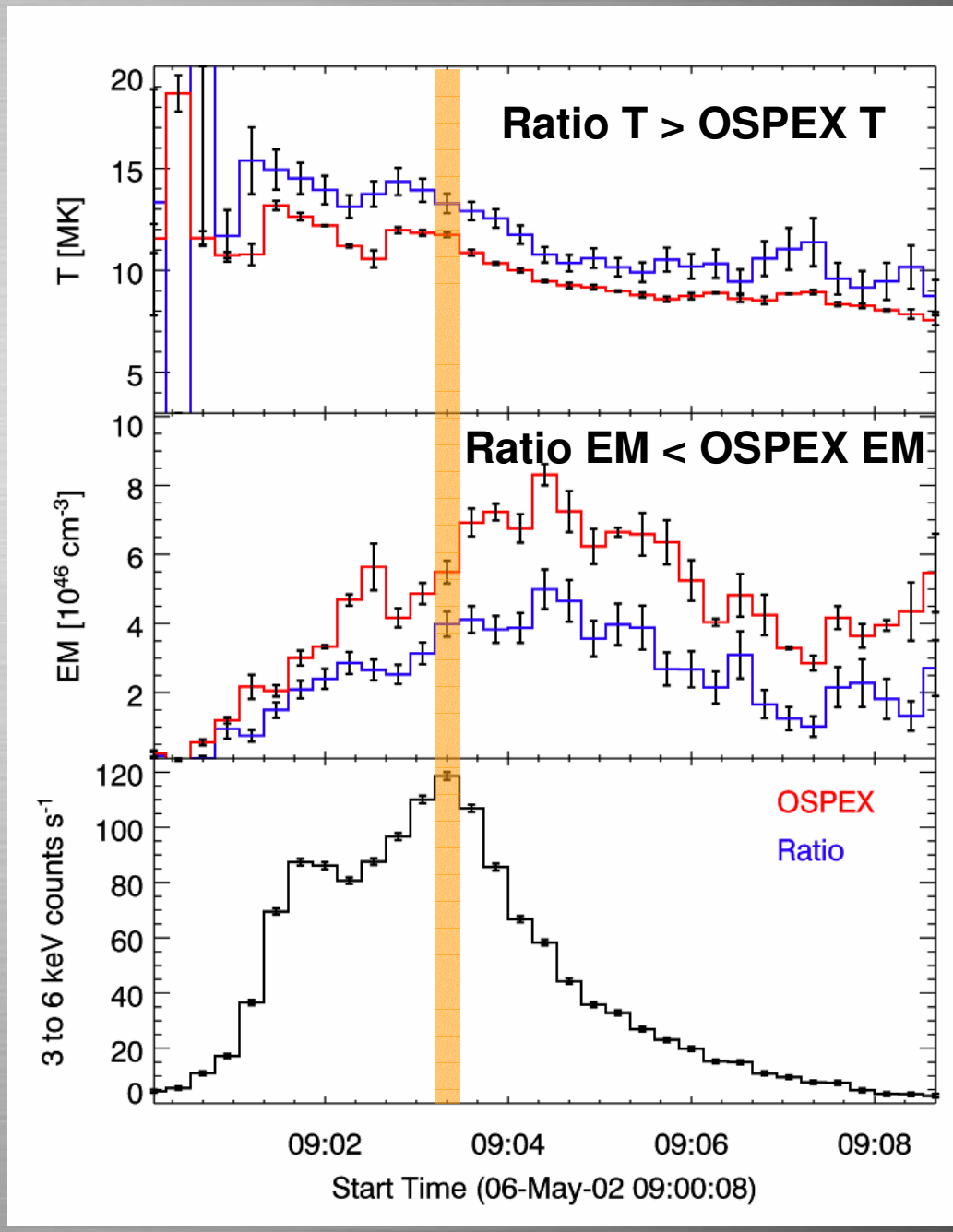
Peak Time



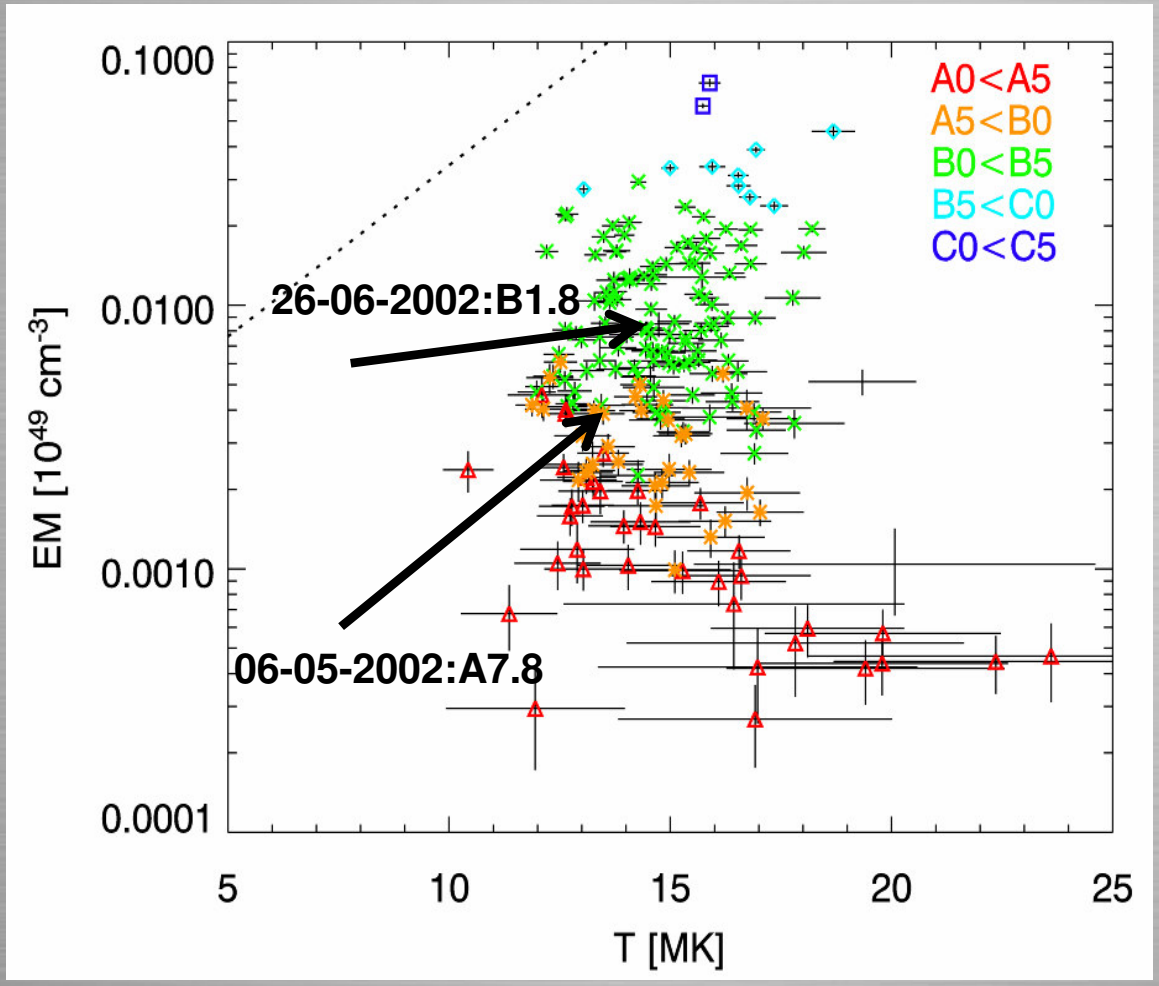
Disagreement but only 20% out: which to believe?

Peak Time





T vs EM at Peak Time



Emission Measure vs Temperature at the time of peak i 3-6 keV for 199 flares.

Colour coded by background subtracted GOES class

Dotted line from Feldman et al [1996]: Average BCS T vs EM from BCS, GOES (1-8)Å and (0.5-4)Å

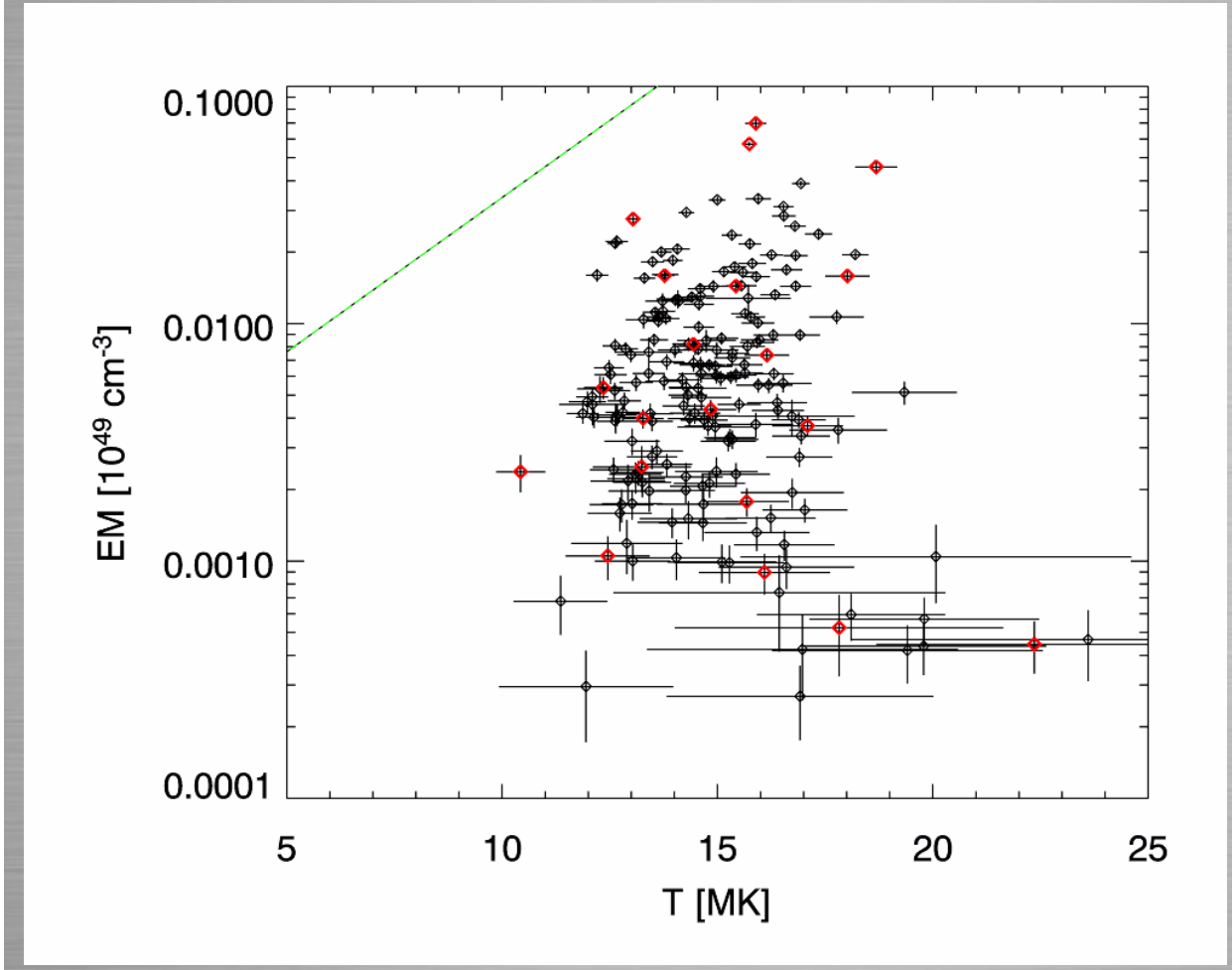
No clear correlation

All T >10 MK

RHESSI sees higher T or lower EM

Bias introduced by ratio method, but we know what this is and can correct for it?

OSPEX Comparison



Ratio←→OSPEX

Comparison of Ratio and OSPEX EM, T at the time of the peak in 3-6 keV

OSPEX produces generally lowe T and higher EM

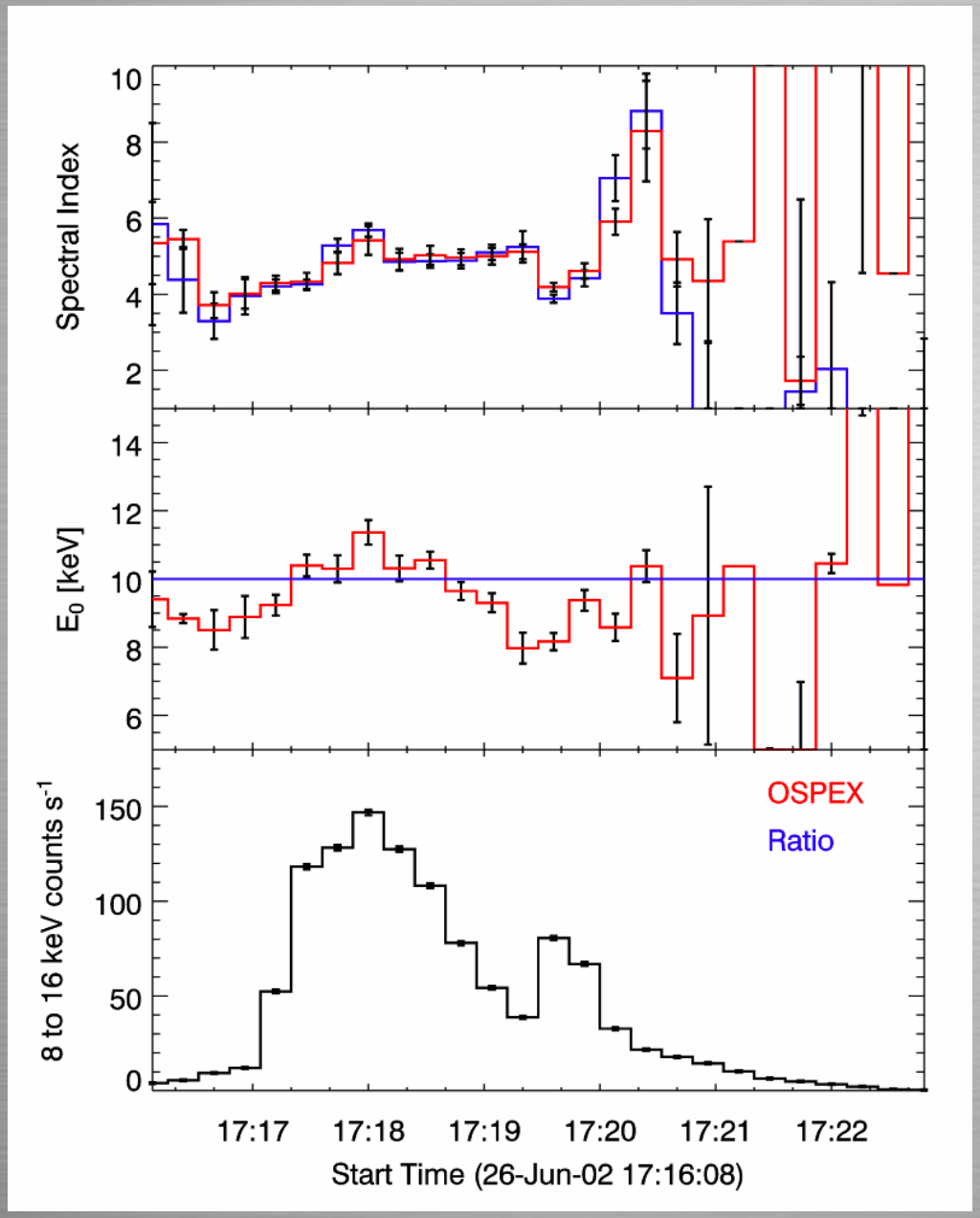
OSPEX results still lower than Feldman et al [1996]: RHESSI higher T and/or lower EM

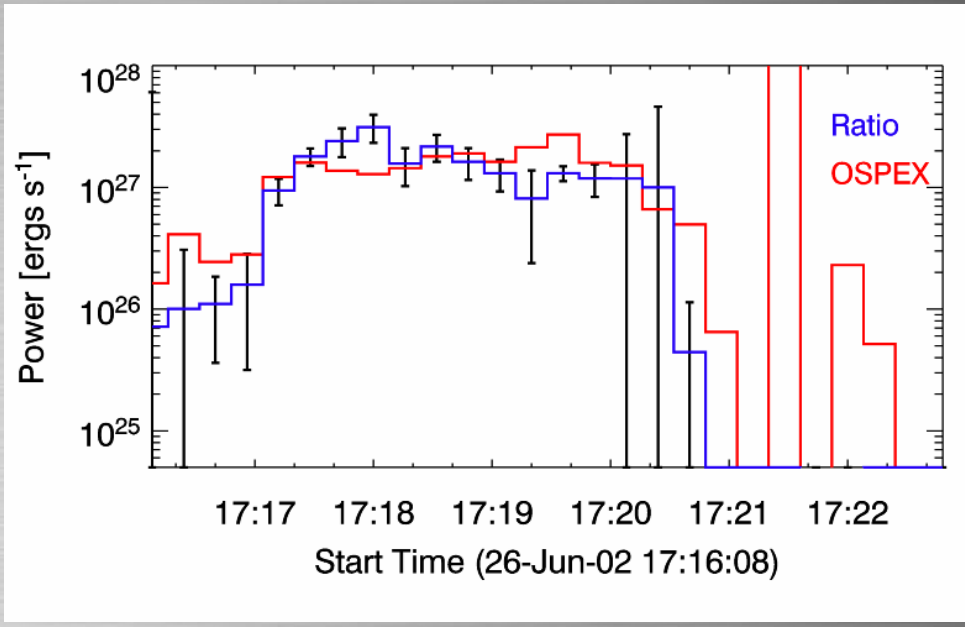
No clear correlation again

So Ratio overestimating therma component and underestimating non-thermal part?

But we understand the bias it is introducing

Non-Thermal Energy





Calculate energy in non-thermal energy using Brown [1971], Lin et al [2001]:

$$P(> E_0) \propto \gamma^2(\gamma-1)\beta(\gamma-0.5,1.5)E_0^{-(\gamma-}$$

June Total Energy= 5.0x10^{30} ergs !!

A Bit High for B Class?

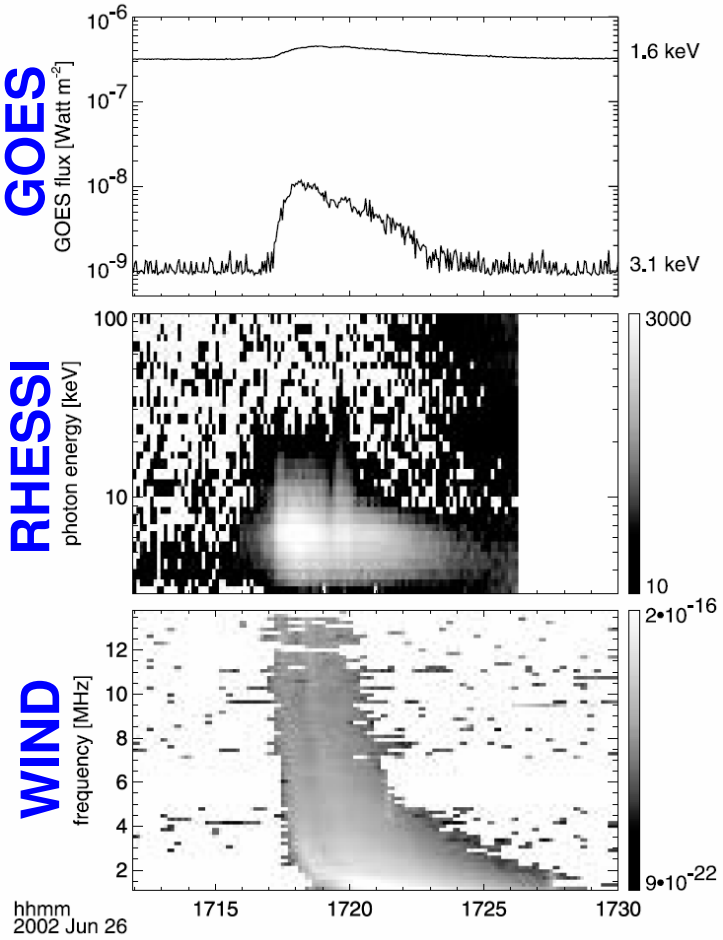
- But Steep Spectrum
- And E_0=10 keV, normally 25 keV so 10^{-3} smaller if using 25 keV (but no counts >20 keV!)

$$\frac{E_{25}}{E_{10}} = 2.5^{-\gamma} \approx 10^{-2} - 10^{-3}$$

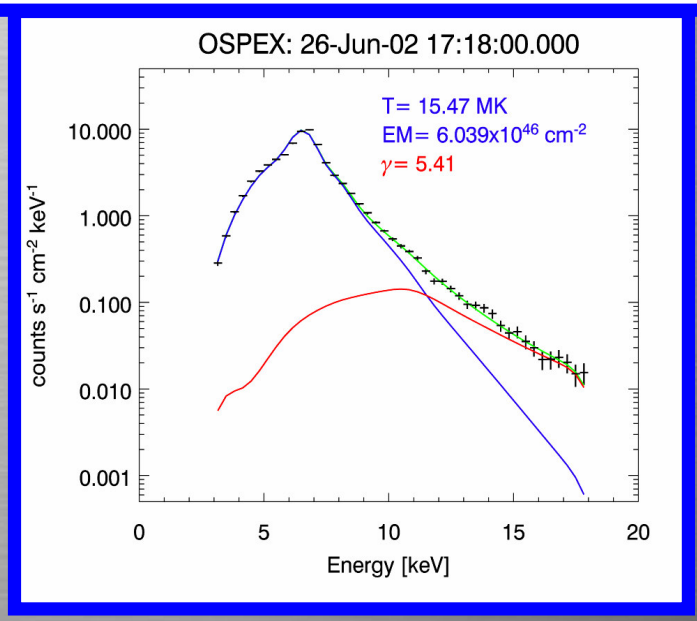
Obvious Question

So is this: *Hot Thermal + Non-Thermal*

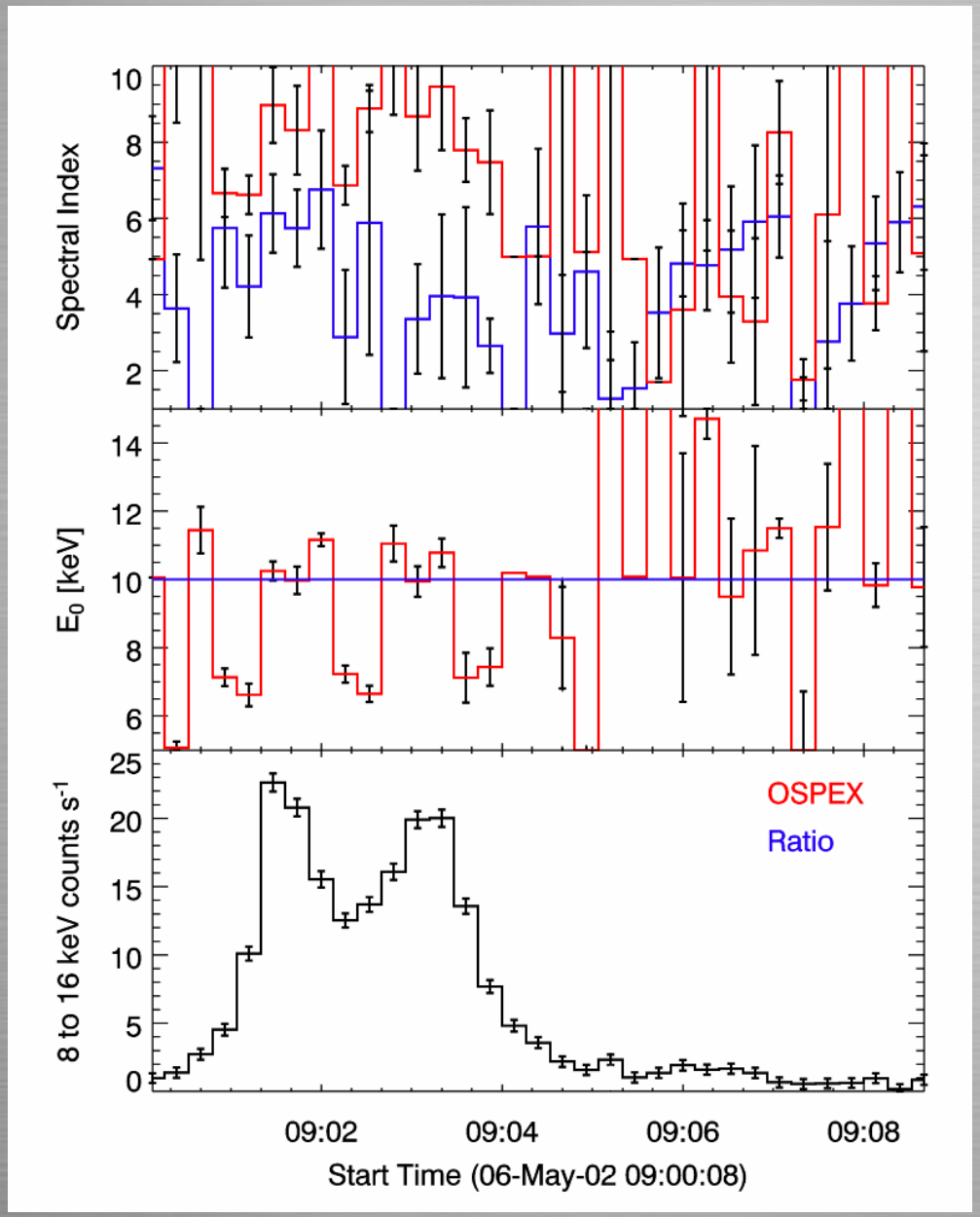
or something else like *Hot Thermal + Super-Hot Thermal?*

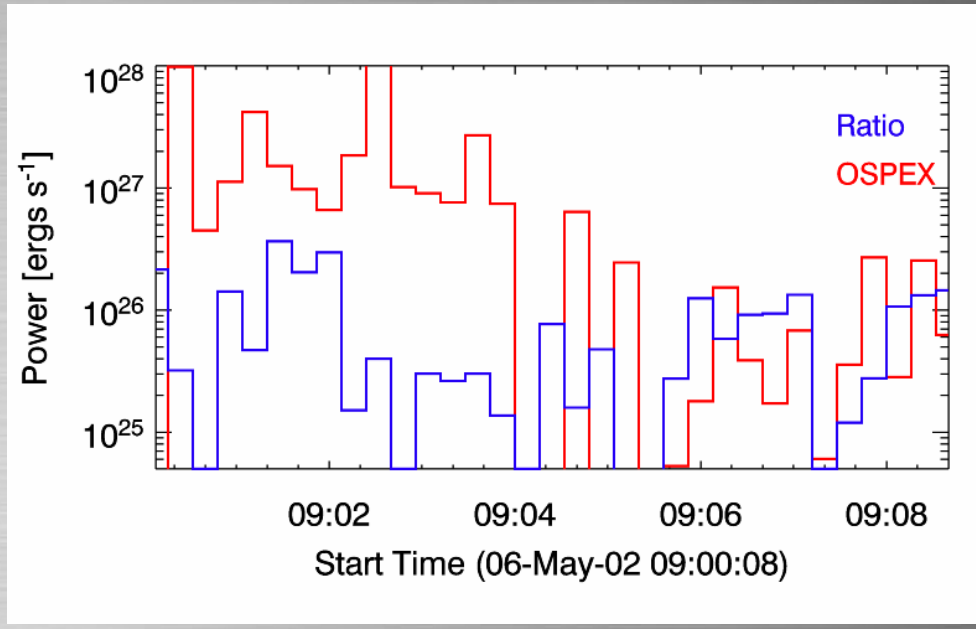


Probably non-thermal: Spectrum fitting works for non-thermal, observe type III radio burst [Liu et al. 2004 ApJ]



More Non-Thermal Energy



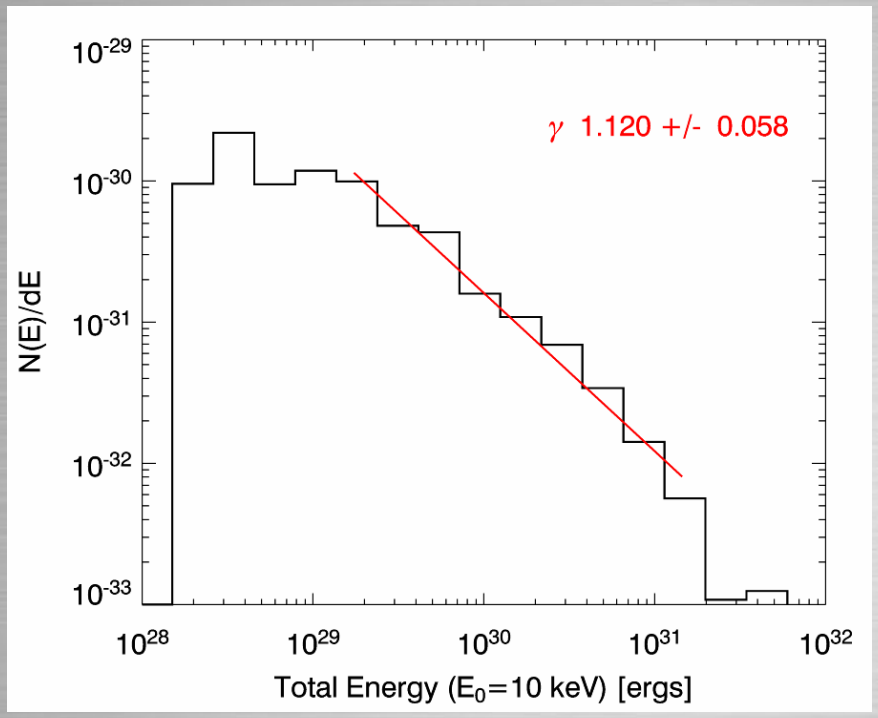


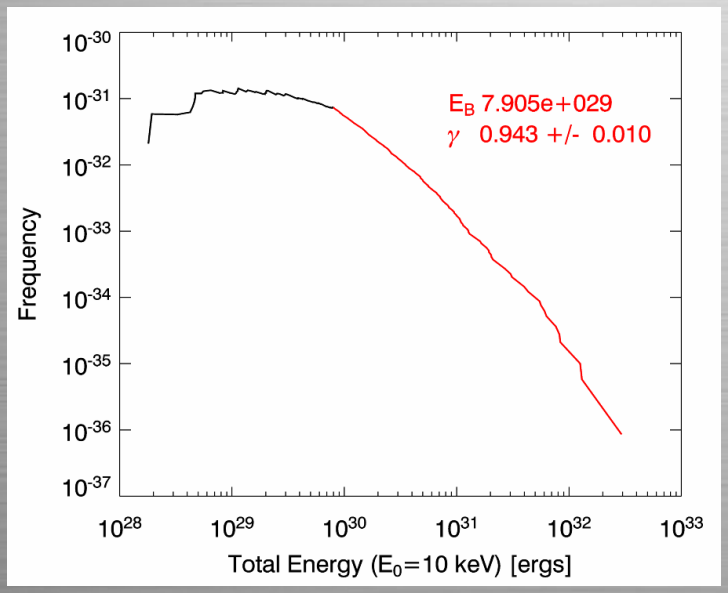
For a smaller event have overestimated thermal component and so underestimated non-thermal energy.

Even OSPEX which does a better job still has problems.

From Ratio only 1.6x10^{29} ergs in this event ! (have only used time bins with less than 100% error)

Non-Thermal Energy Distribution





For Total Energy of 199 flares only used P with error < 100%.

All energies found from Ratio method: so smaller events have *underestimated energies* as thermal component overestimated

Get an index of ~1.1

If using E_0=25 keV energies would be shifted down by 10^2 or 10^3, though few counts > 20 keV

Can also get distribution using Parnell & Jupp [2000] method which is *independent of bin size*, giving an *objective* measure of the index. This time about 0.94

Conclusions

- RHESSI excellent for observing microflares
  - These are small flares that occur in active regions
- They are hot (>10 MK) with presence of Fe K Complex
- Difficult to interpret thermal vs non-thermal spectrum or super-hot component
  - Possibly a lot of energy in the non-thermal electrons
  - Distribution (though biased) with index ~1

Future Missions

- What about the current one, RHESSI ?
  - Still got 1,000s of events to analyse
  - Quiet Sun gives great opportunity for 10,000s more
  - RHESSI does and will provide vital information about the energy input of these events into the corona