Understanding the Coronal Response to Impulsive Heating Events:

# Science with the Coronal Plasma Imaging Calorimeter (CPIC)

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# Broad-band Solar X-Ray Spectroscopy

- Excellent selection of hundreds of lines with formation temperatures between 1-30MK, and density sensitive lines covering temperatures from 2-10MK.
- Continuum emission
- Identify non-equilibrium effects and the transition to thermal equilibrium
- Characterize abundances and study the FIP effect
- Detect non-thermal electrons from small hard flares
- Modeling of X-ray Spectra is well developed and allow scientists to compare detailed forward models with state-of-the-art observation

Density Sensitive Lines

| ION | log $T_{max}$[K] | log $n_e$ [$cm^2$] | resonance ( r ) [Å] | intercombination ( i ) [Å] | forbidden (f ) [Å] |
|---|---|---|---|---|---|
| Si XIII | 7.0 | 13-14 | 6.648 | 6.685,6.688 | 6.740 |
| Mg XI | 6.8 | 12-13 | 9.169 | 9.228,9.231 | 9.314 |
| Ne IX | 6.6 | 11-12 | 13.446 | 13.550,13.553 | 13.699 |
| O VII | 6.4 | 10-11 | 21.602 | 21.801,21.804 | 22.098 |
| N VI | 6.15 | 9-10 | 28.787 | 29.0843 | 29.535 |

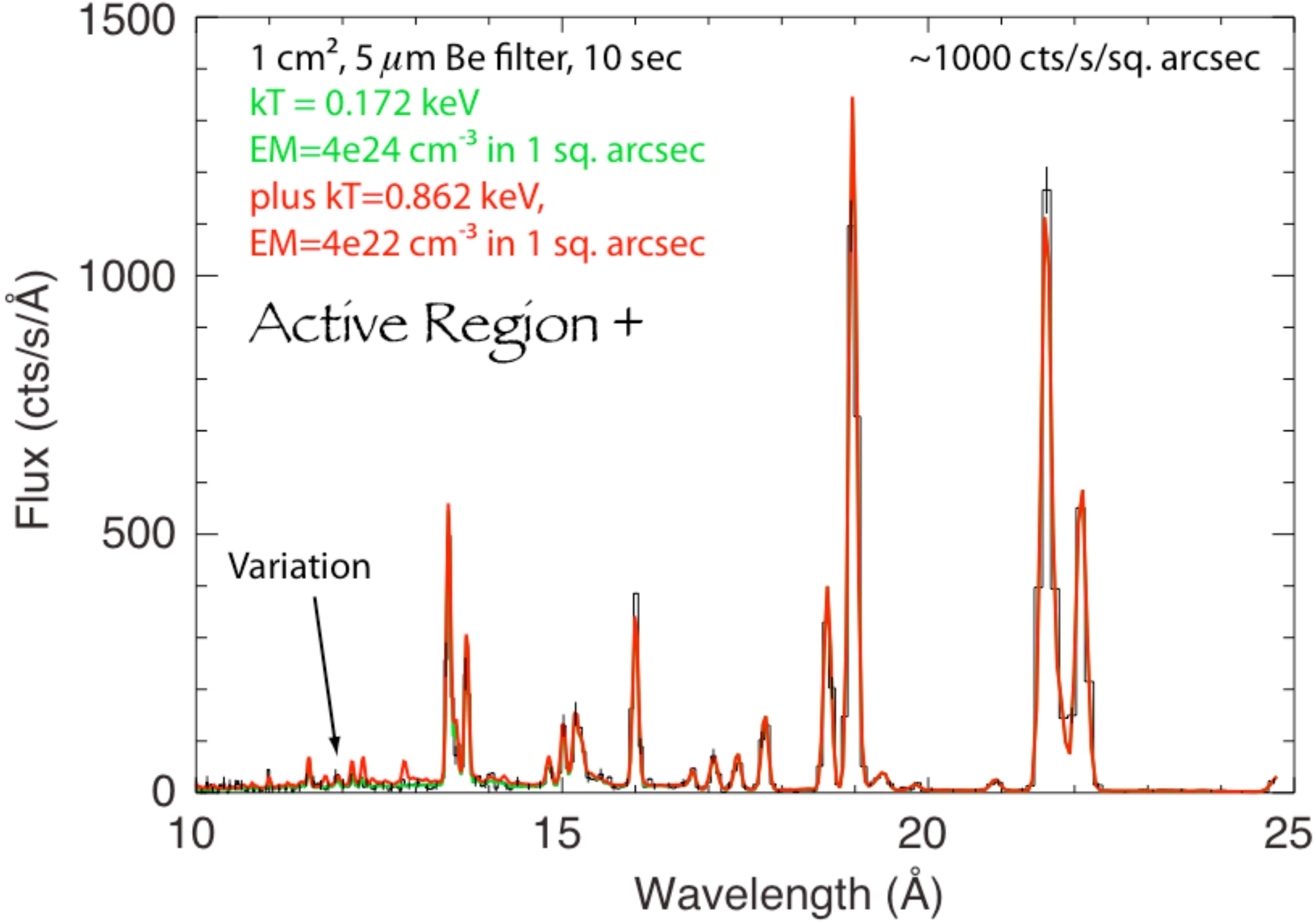
# Detector Capabilities

- 3 eV spectral resolution
- 1-25 A wavelength range
- imaging spectroscopy on 32x32 pixels
- 2”  per pixel with a 64” FOV (or 3” with 96” FOV)
- 1 sec time cadence

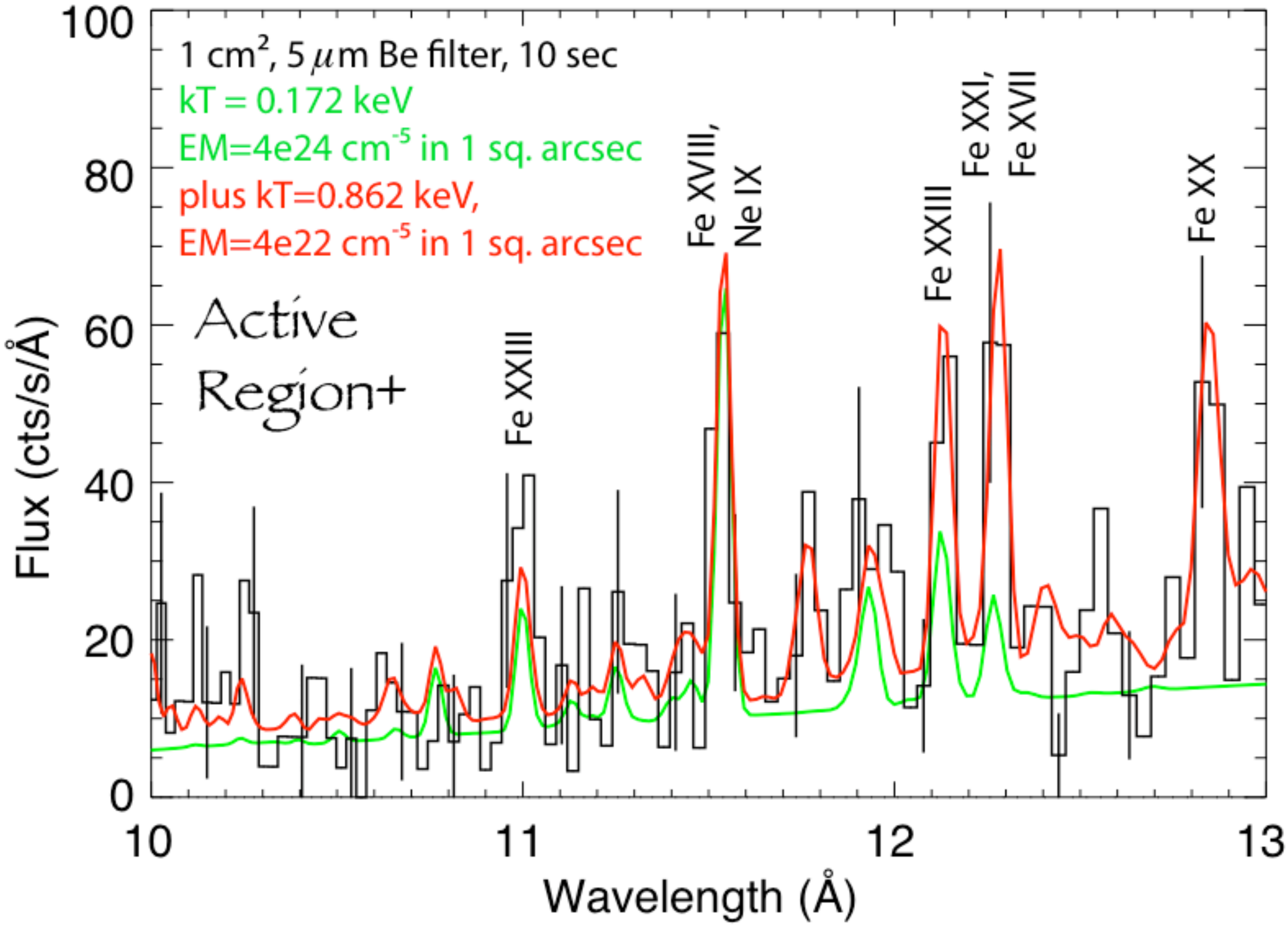
# Active Region Science topics

- Hot Plasma in closed magnetic configurations
- Follow the heating and cooling life cycle of AR loops
- Map flows and abundance structure
- Evolution on the radiative timescales (~200s)
  - The instrument can detect small amount of hot plasma mixed with cooler plasma
  - Example: 10MK plasma with 1% of the EM of a 2MK plasma

# Hot component has 1% EM of AR component



Hot component has 1% EM of AR component



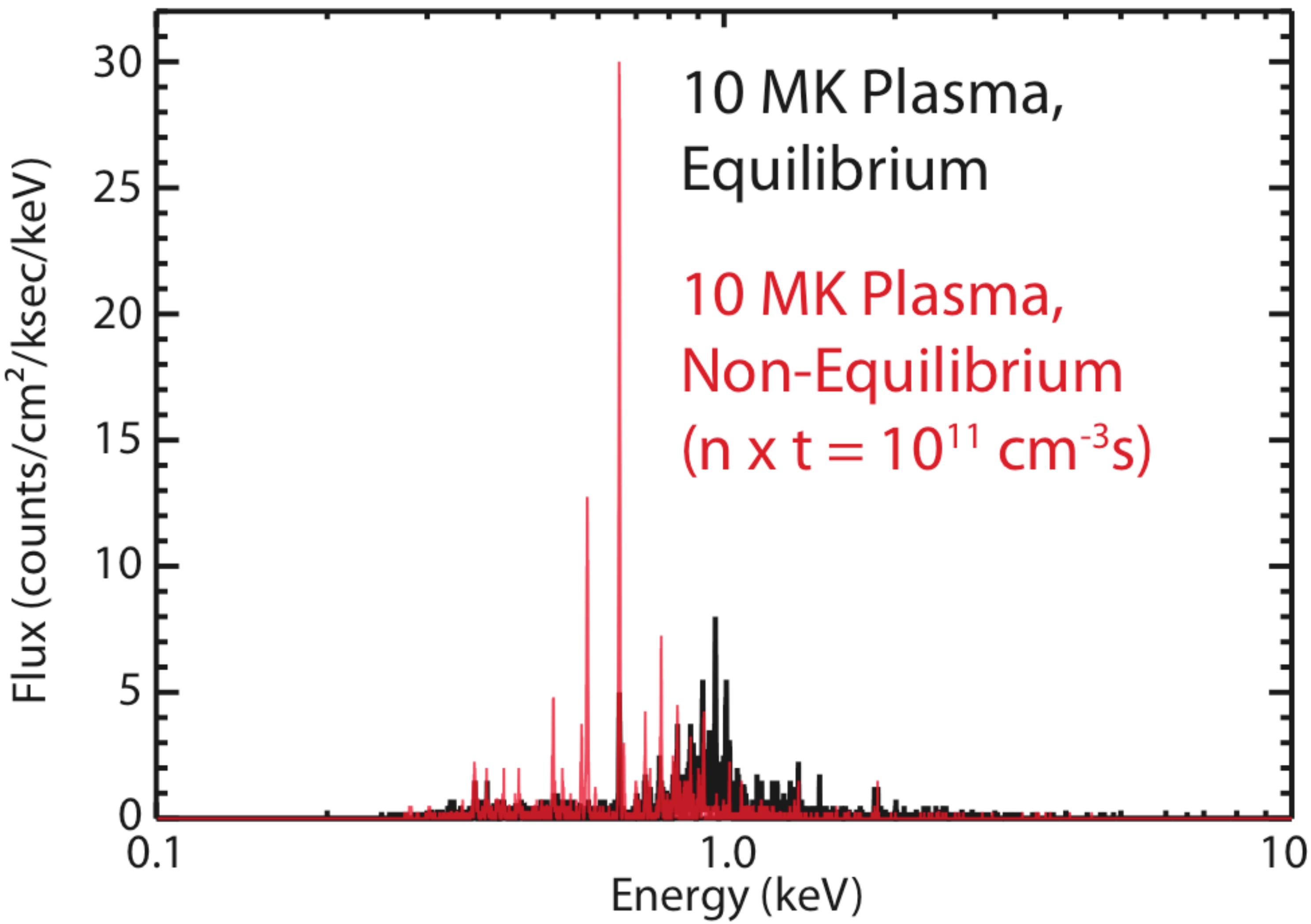
# Active Region Science topics

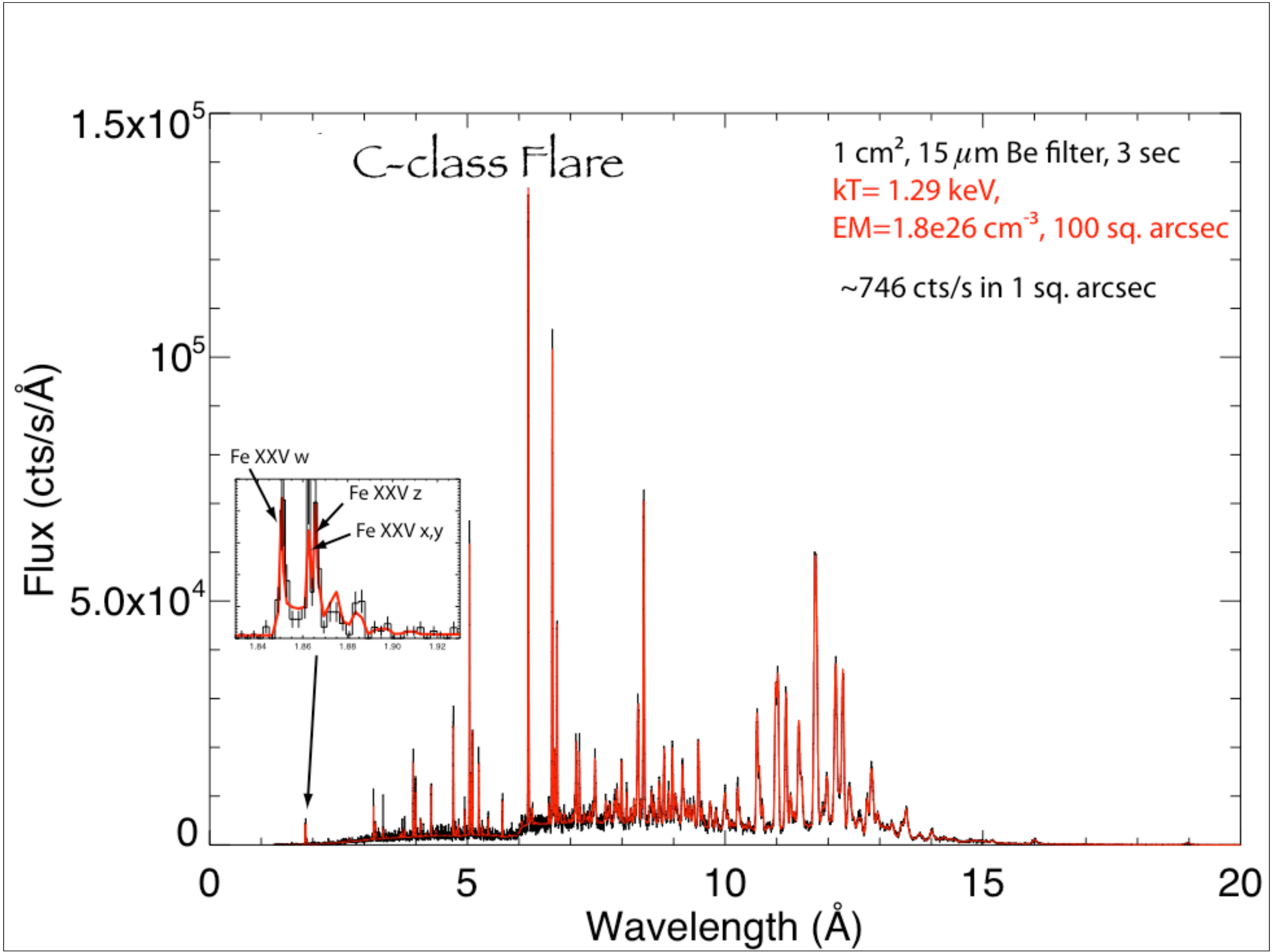
- Hot Plasma in open magnetic configurations
- Outflows at the edge of active regions
  - DEM for this is down by a factor of 10–100 from AR
    - Long integration times needed for this study
  - Velocity as a function of temperature
  - Velocity maps
  - Abundance maps

# Flare Science topics

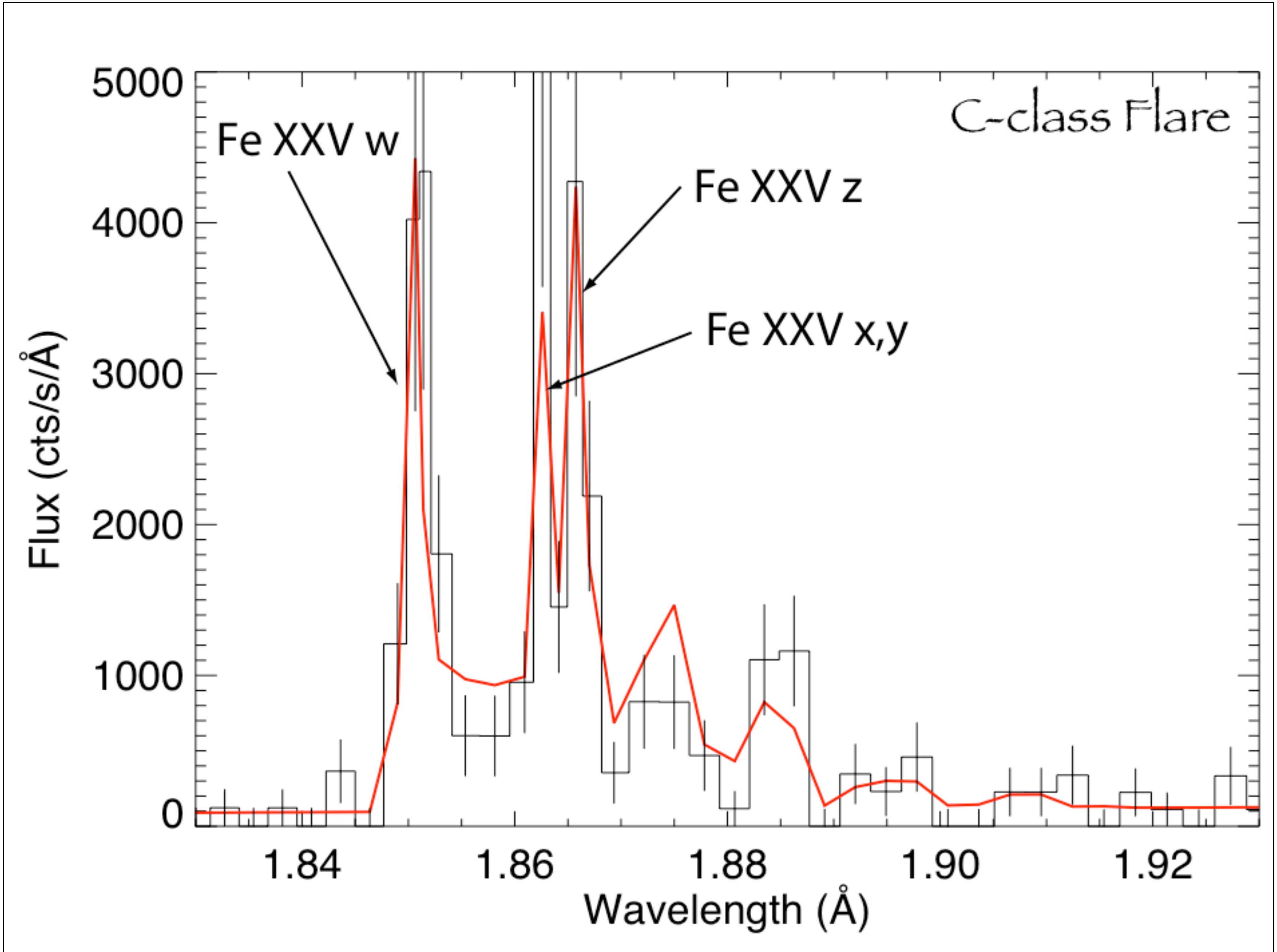
- Dynamic range achieved by using filters of different thickness
- Evolution on energetic particle transit times (~10s)
- Thermal evolution of an impulsively heated plasma
  - Non-ionization equilibrium effects
  - High speed flows -> broadening of emission lines
- Build reliable DEM maps

# Ionization equilibrium

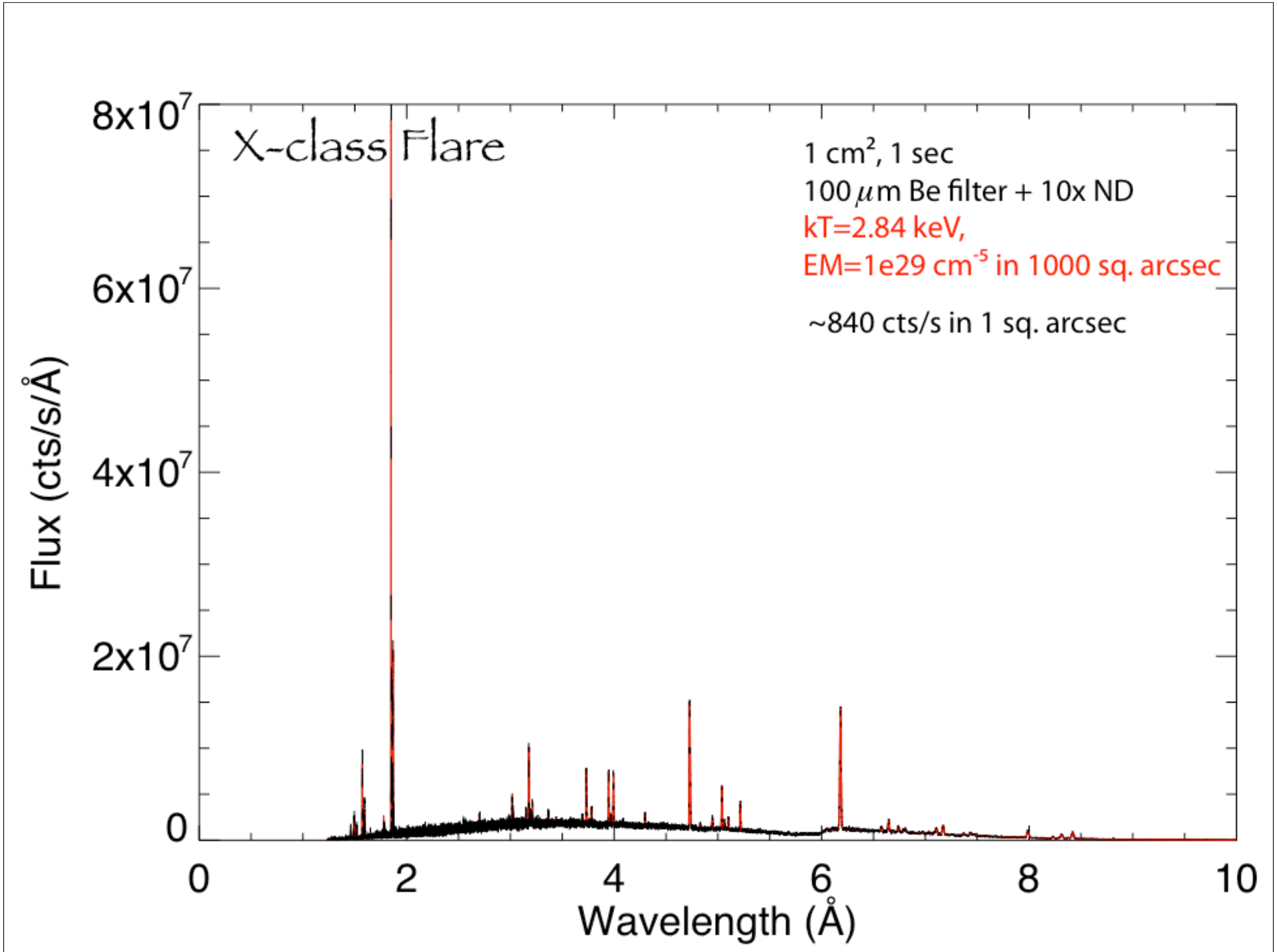




C-class Flare
1 cm², 15 μm Be filter, 3 sec
kT= 1.29 keV,
EM=1.8e26 cm⁻³, 100 sq. arcsec
~746 cts/s in 1 sq. arcsec
Fe XXV w
Fe XXV z
Fe XXV x,y
Flux (cts/s/Å)
Wavelength (Å)
1.5x10^5
10^5
5.0x10^4
0
5
10
15
20



C-class Flare
Fe XXV w
Fe XXV z
Fe XXV x,y
Flux (cts/s/Å)
Wavelength (Å)
5000
4000
3000
2000
1000
0
1.84
1.86
1.88
1.90
1.92


X-class Flare
1 cm², 1 sec
100 μm Be filter + 10x ND
kT=2.84 keV,
EM=1e29 cm⁻⁵ in 1000 sq. arcsec
~840 cts/s in 1 sq. arcsec
Flux (cts/s/Å)
Wavelength (Å)
8x10⁷
6x10⁷
4x10⁷
2x10⁷
0
0
2
4
6
8
10

# Flare Science topics

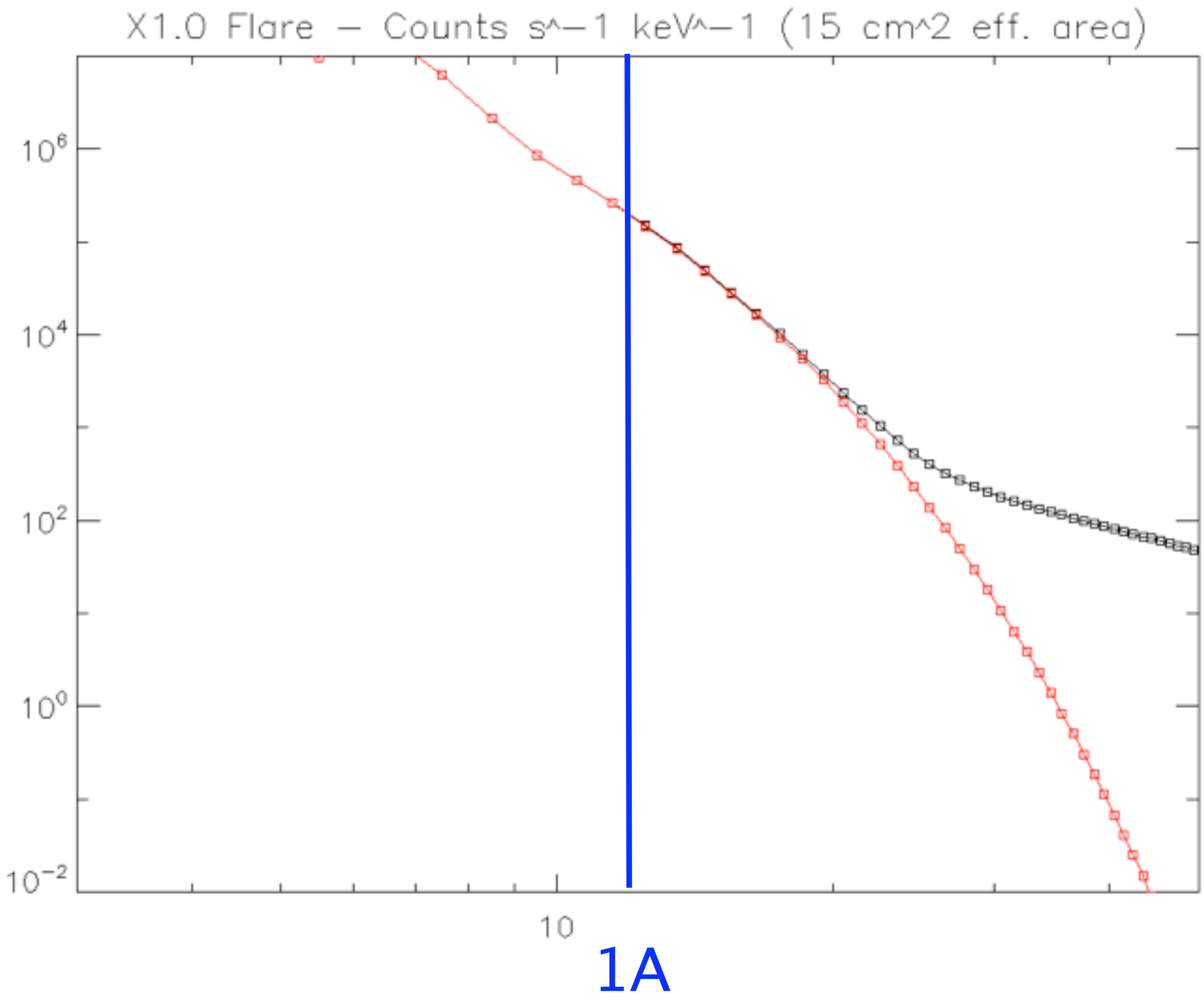
- Diagnostics of evaporation
  - Abundance effects
  - Upflows & downflows
- Dynamic energy balance
  - Pressure evolution
  - Non-thermal contribution
  - Kinematic pressure

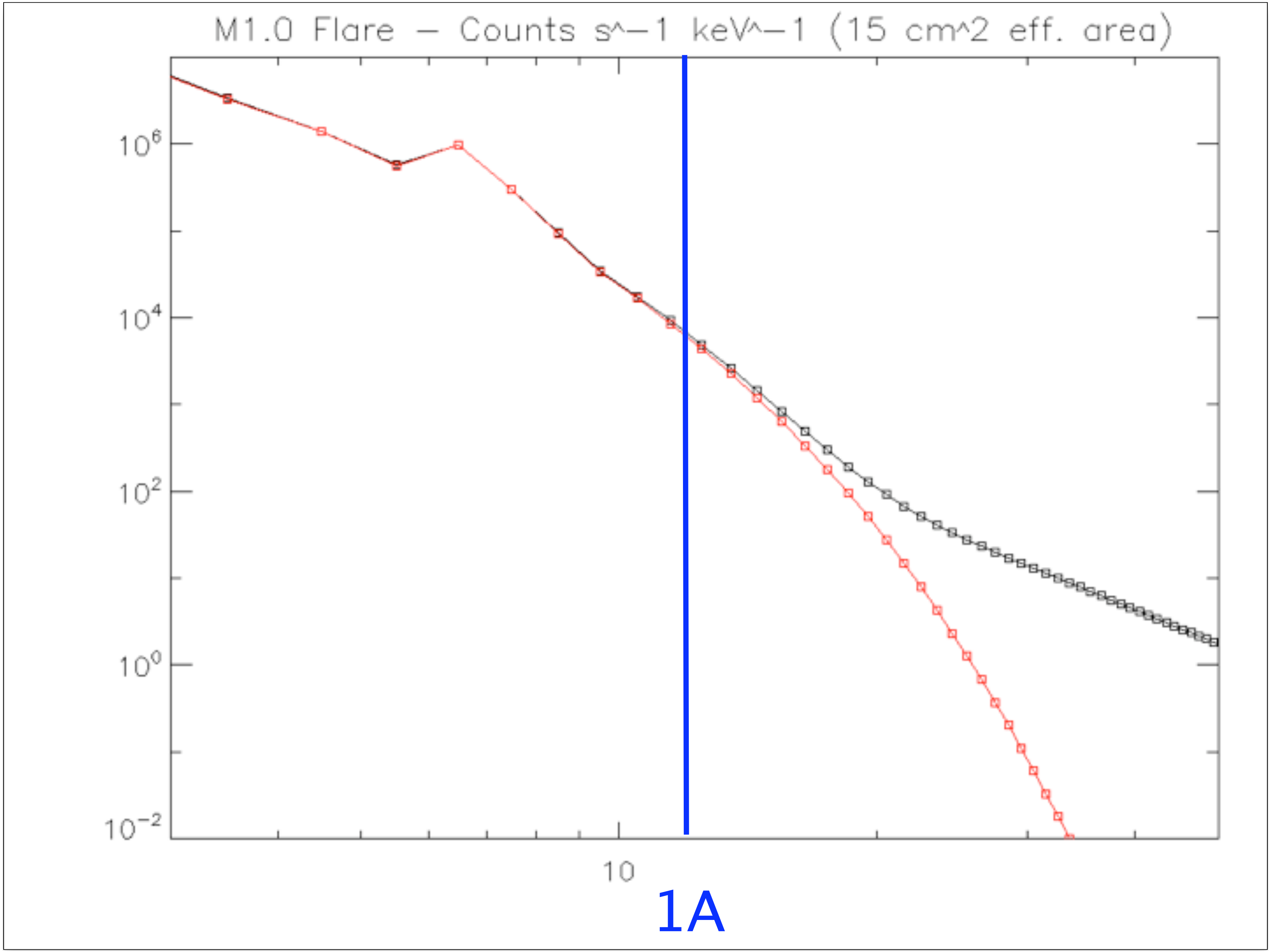
# Flare Science topics

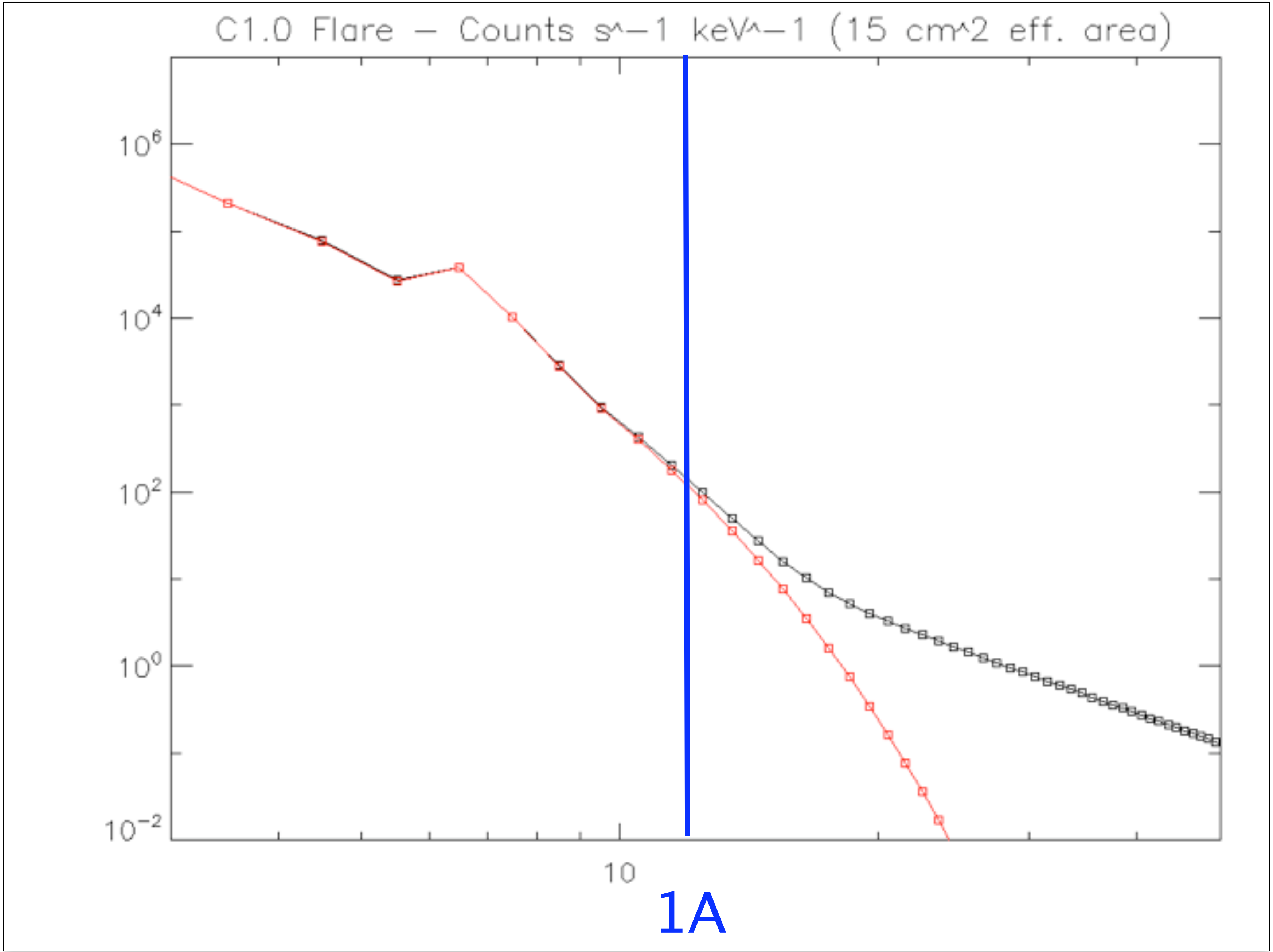
- Observe Recombination edges
- Observe fluorescence lines
- Observe Line broadening by turbulence

# Non–thermal emission

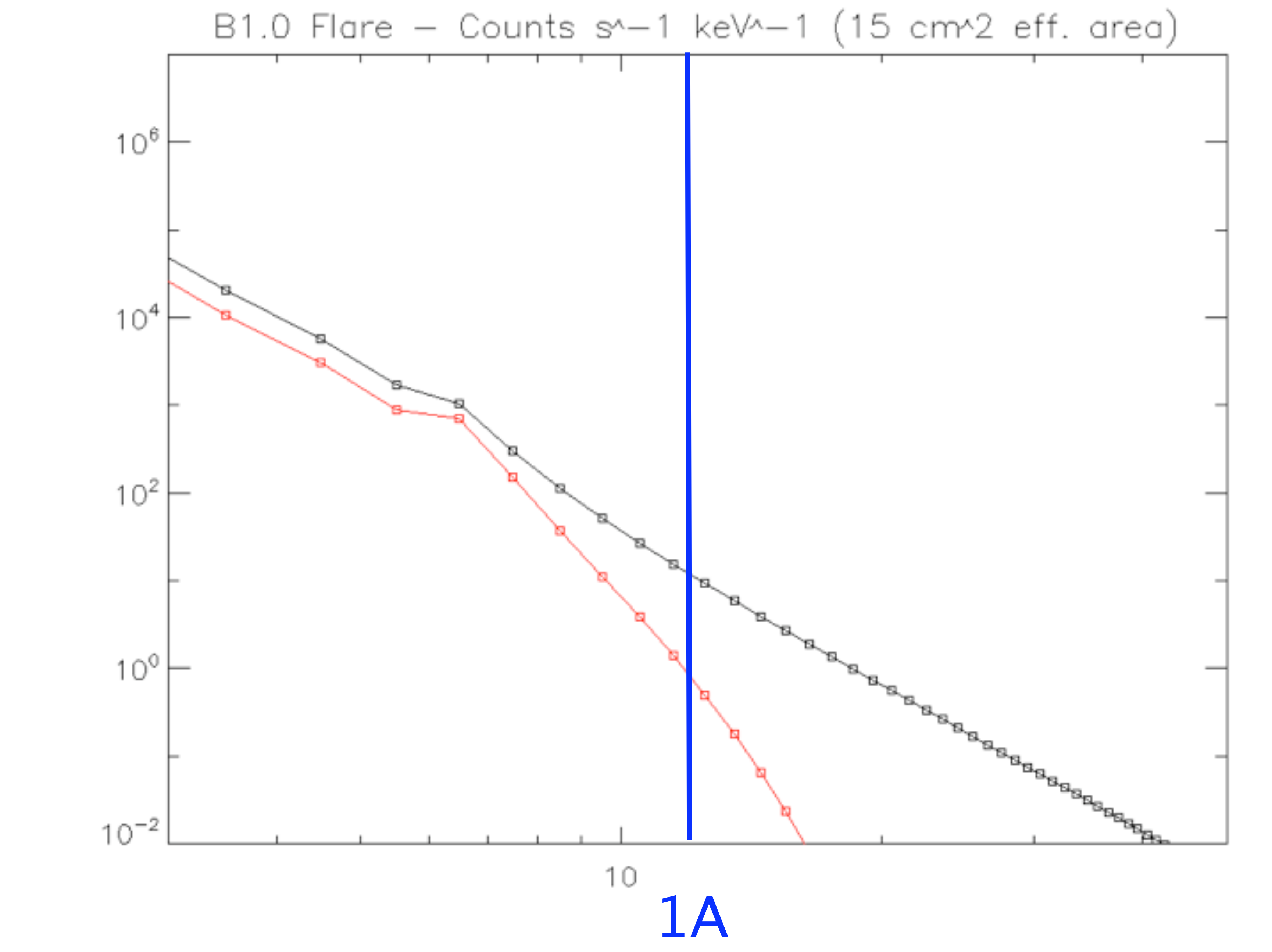
- Limited by highest energy available
- Can be observed in 10–15 keV range in small hard flares
- Hidden by the thermal continuum in large flares
- Different position of thermal sources and non–thermal sources will allow better discrimination


X1.0 Flare - Counts s^-1 keV^-1 (15 cm^2 eff. area)
10^6
10^4
10^2
10^0
10^-2
10
1A


M1.0 Flare – Counts s^–1 keV^–1 (15 cm^2 eff. area)
10^6
10^4
10^2
10^0
10^–2
10
1A



C1.0 Flare – Counts s^-1 keV^-1 (15 cm^2 eff. area)
10^6
10^4
10^2
10^0
10^-2
10
1A



B1.0 Flare – Counts s^-1 keV^-1 (15 cm^2 eff. area)
10^6
10^4
10^2
10^0
10^-2
10
1A

# Quiet Sun

- Quiet Sun studies require long integration times due to the low sensitivity of the telescope to cool plasma. Summing spectra over 100s of seconds does not introduce significant errors.
  - Separate XPBs from QS
  - Is there a hot component to QS spectrum?
  - XPB flares - any non-thermal component
  - High velocity flows in X-ray Jets
  - High temperatures in X-ray Jets reconnection sights
  - Quiescent XBPs spectral properties as a function of lifetime and size

# How many photons?

- Our expectation on the number of photons needed in each spectra:
  - 300 photons => line identification
  - 1000 photons => DEMs, density sensitive lines, velocity resolution ~70km/s, abundances
  - 10,000 photons => Detailed spectroscopy, detection of low EM features.