University of Applied Sciences and Arts
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Combined RHESSI and AIA DEM analysis of solar flares

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Motivation

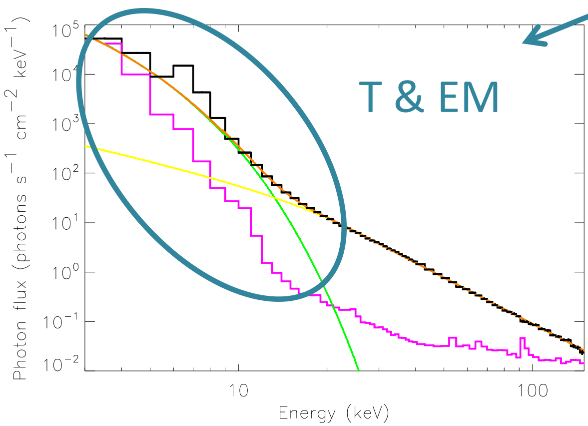
- What is the temperature and emission structure of the flaring chromosphere and corona?
- What is the density profile of a flaring loop?

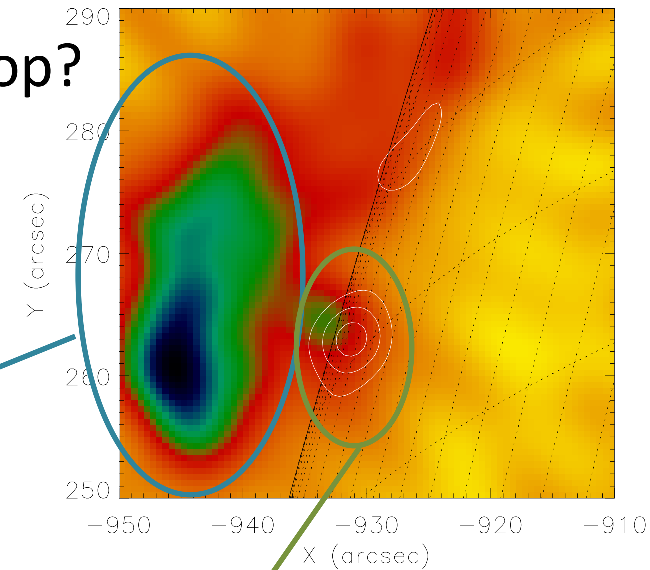
RHESSI: soft X-rays → temperature

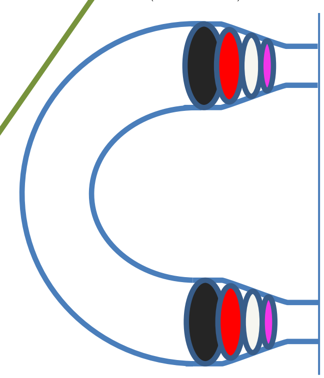
and density of coronal source

hard X-ray footpoints → chromospheric

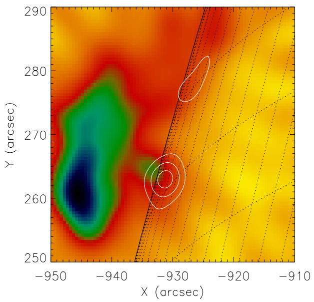
density profile



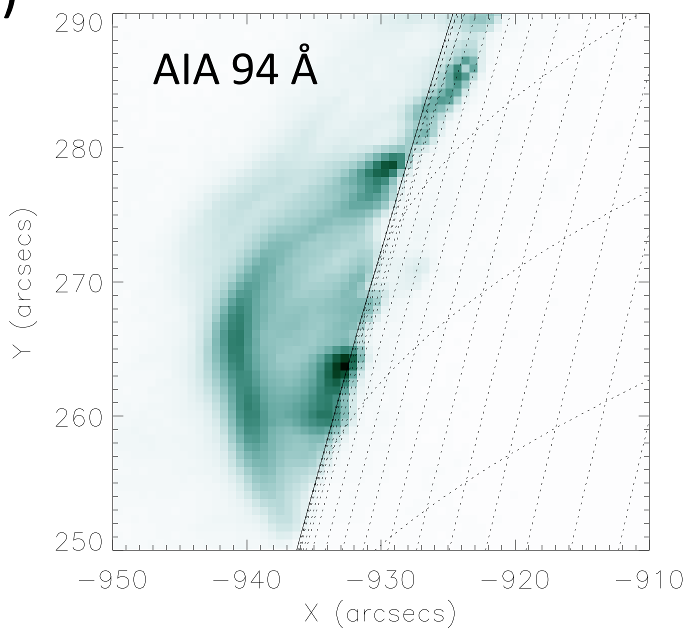




EUV observations → emission measure at different temperatures, depending on wavelength

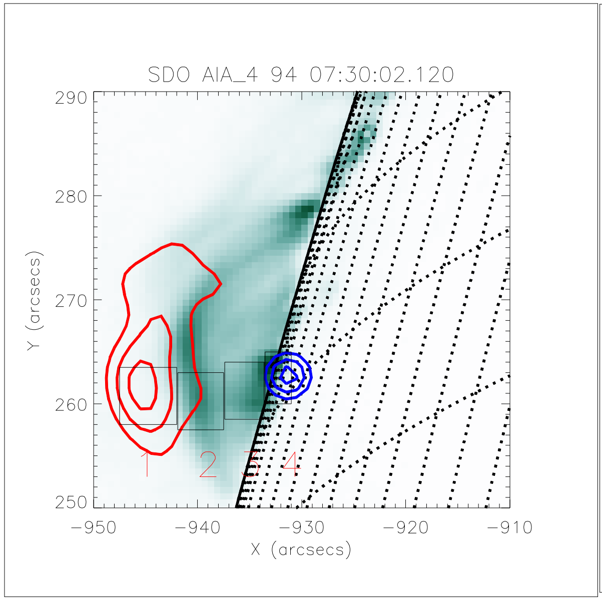


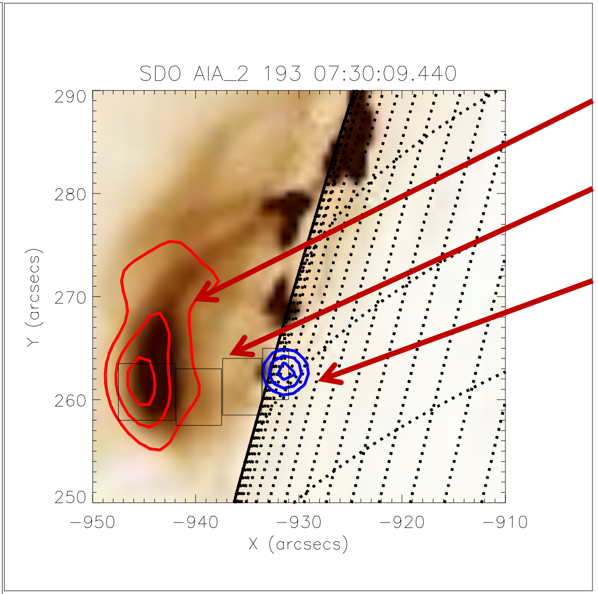
→ differential emission measure (DEM) at different locations



Combining RHESSI and SDO/AIA observations we can reconstruct the thermal parameters and the density along the flaring loop using two independent methods

Observations of a limb flare



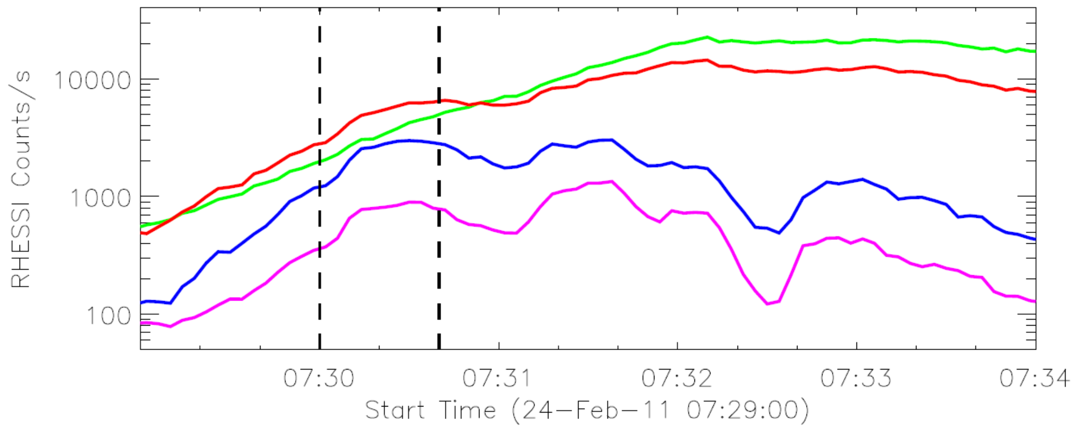


1: soft X-ray coronal source
2: EUV loop
3: EUV loop
4: hard X-ray footpoint

RHESSI SXR source 6 – 12 keV

RHESSI HXR footpoint 30 - 50 keV

- 3 hard X-ray peaks
- focus on the first peak
- 4 regions of interest

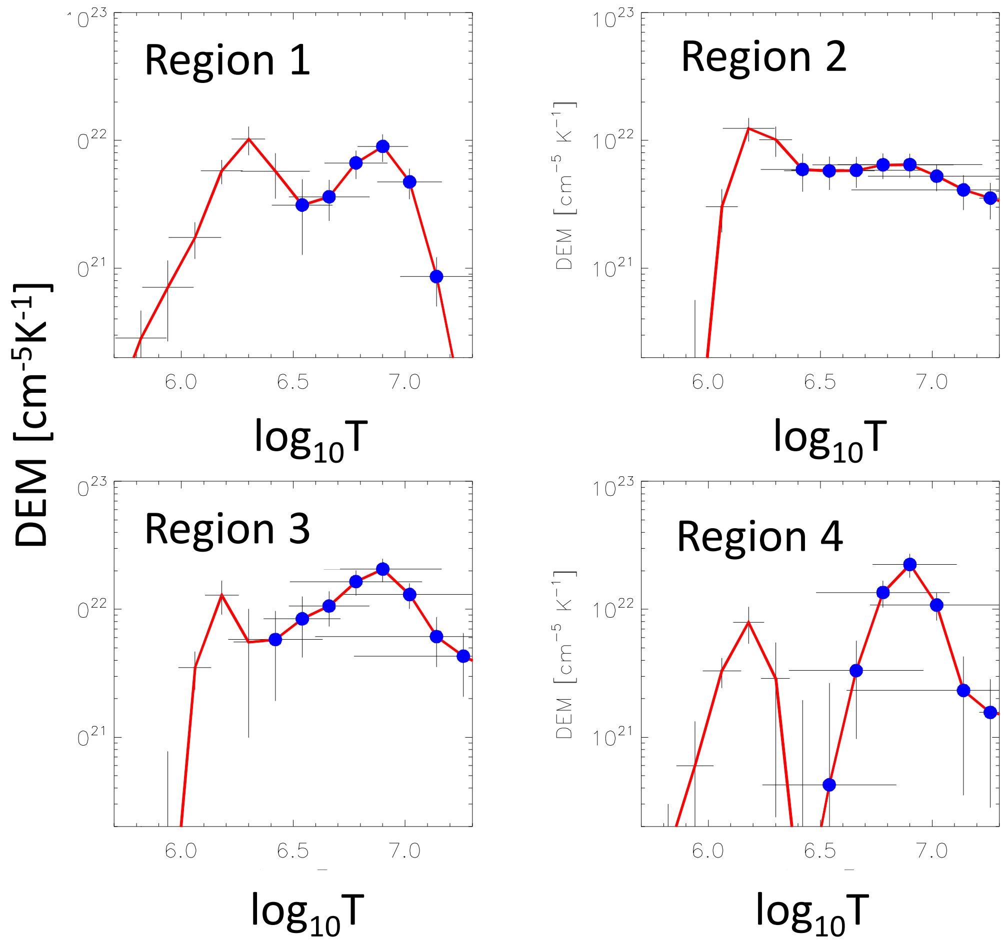


AIA DEM using regularized inversion

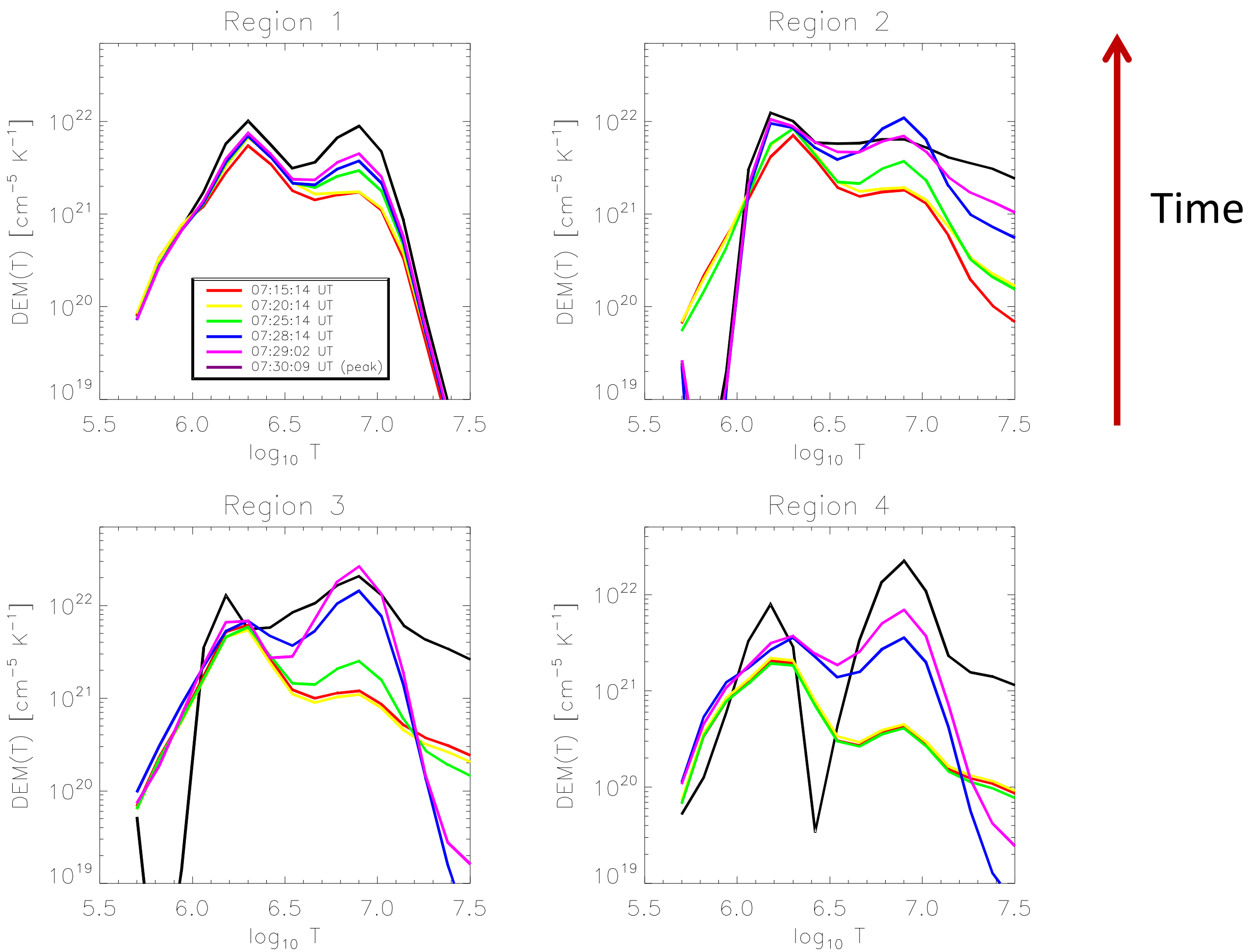
- We use the method developed by Hannah & Kontar (2012) → DEM(T) within the 4 regions of interest

- Two temperature components: around 2 MK and around 8 MK

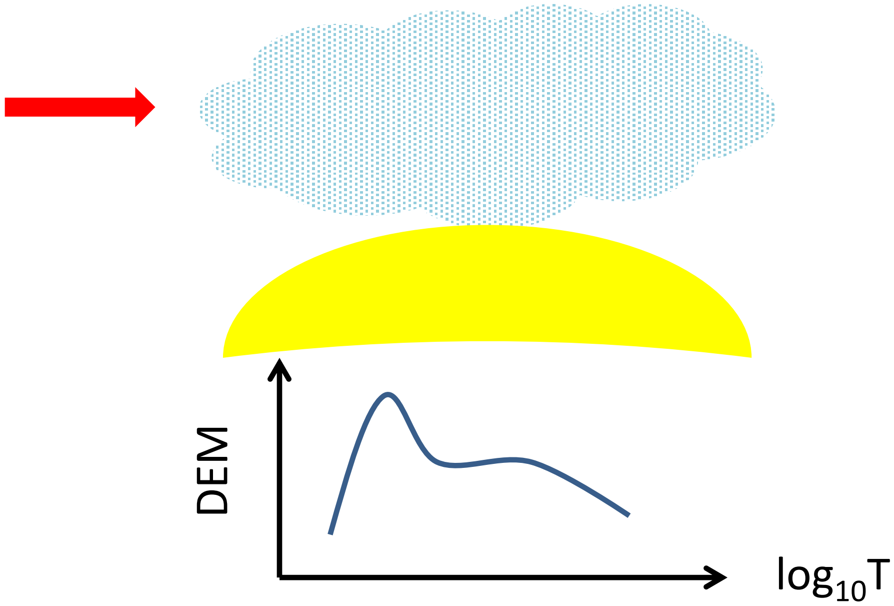
- Are the two components true flare emission?

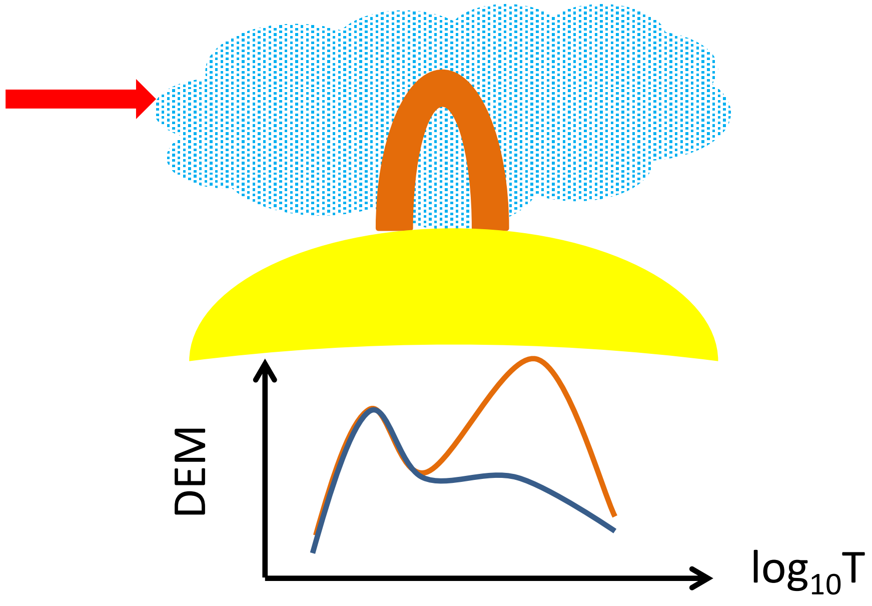


Temporal evolution and low T component



- The low temperature component is present at all times
- The intensity of the high temperature component increases closer to the HXR peak
- Both components are real
- The 2 MK component can be attributed to line of sight effect





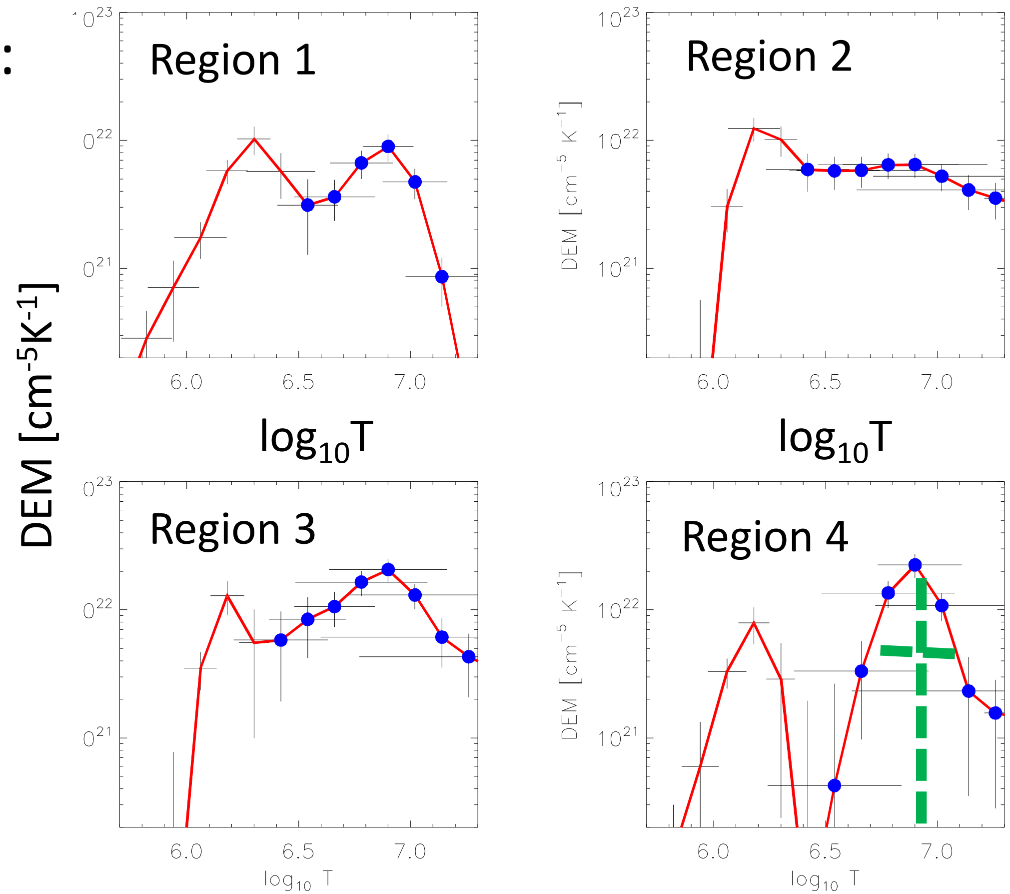
Total emission measure

Total emission measure per area:

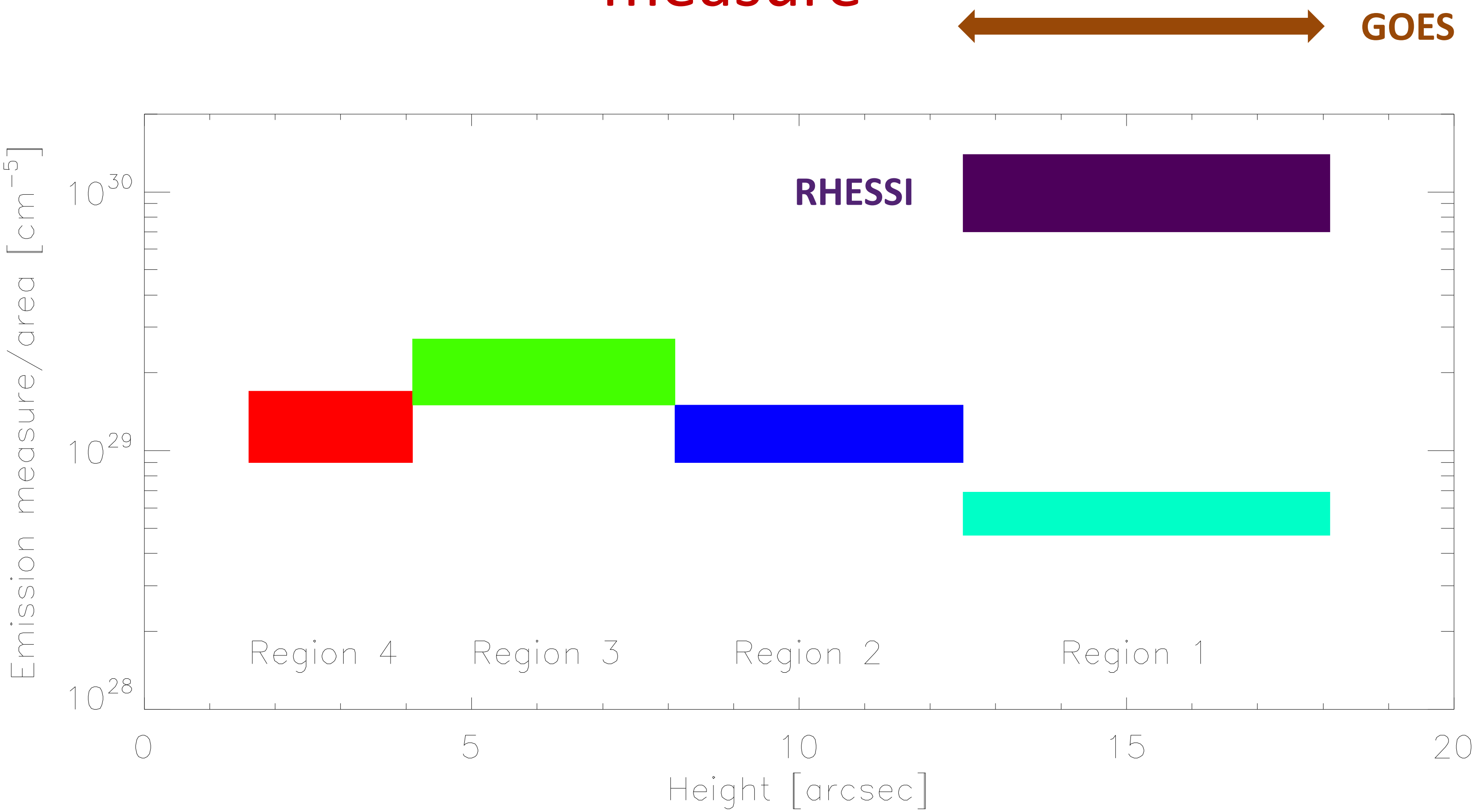
$$\frac{EM}{A} = \int_{T_{min}}^{T_{max}} \xi(T)\mathrm{dT}$$

Peak temperature and sigma:

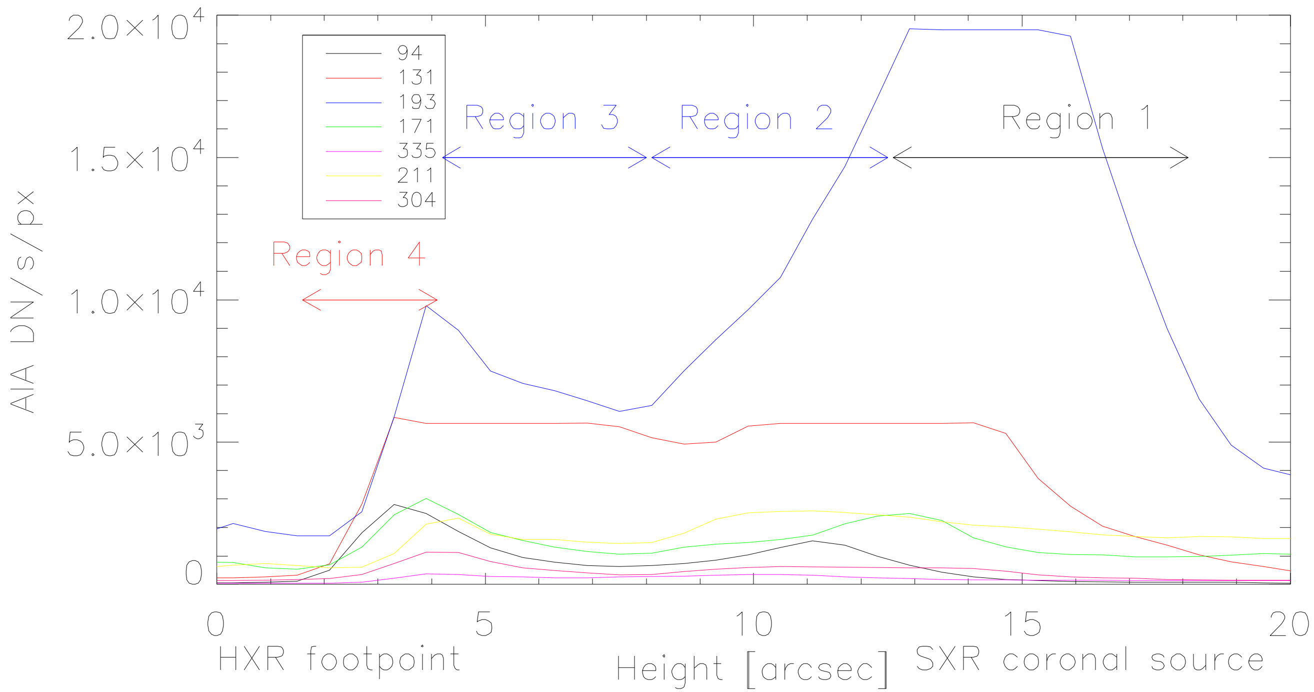
$$T = \frac{\int_{T_{min}}^{T_{max}} \xi(T) \times T\mathrm{dT}}{\int_{T_{min}}^{T_{max}} \xi(T)\mathrm{dT}}$$



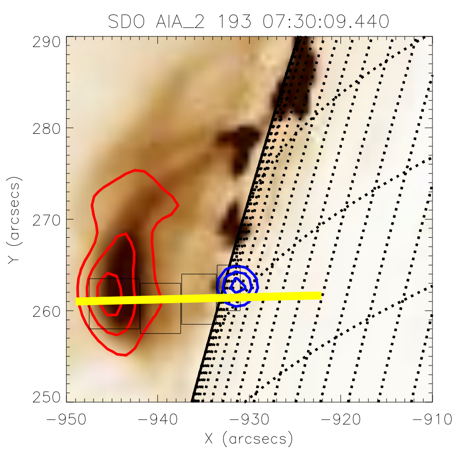
Comparison of thermal parameters: emission measure



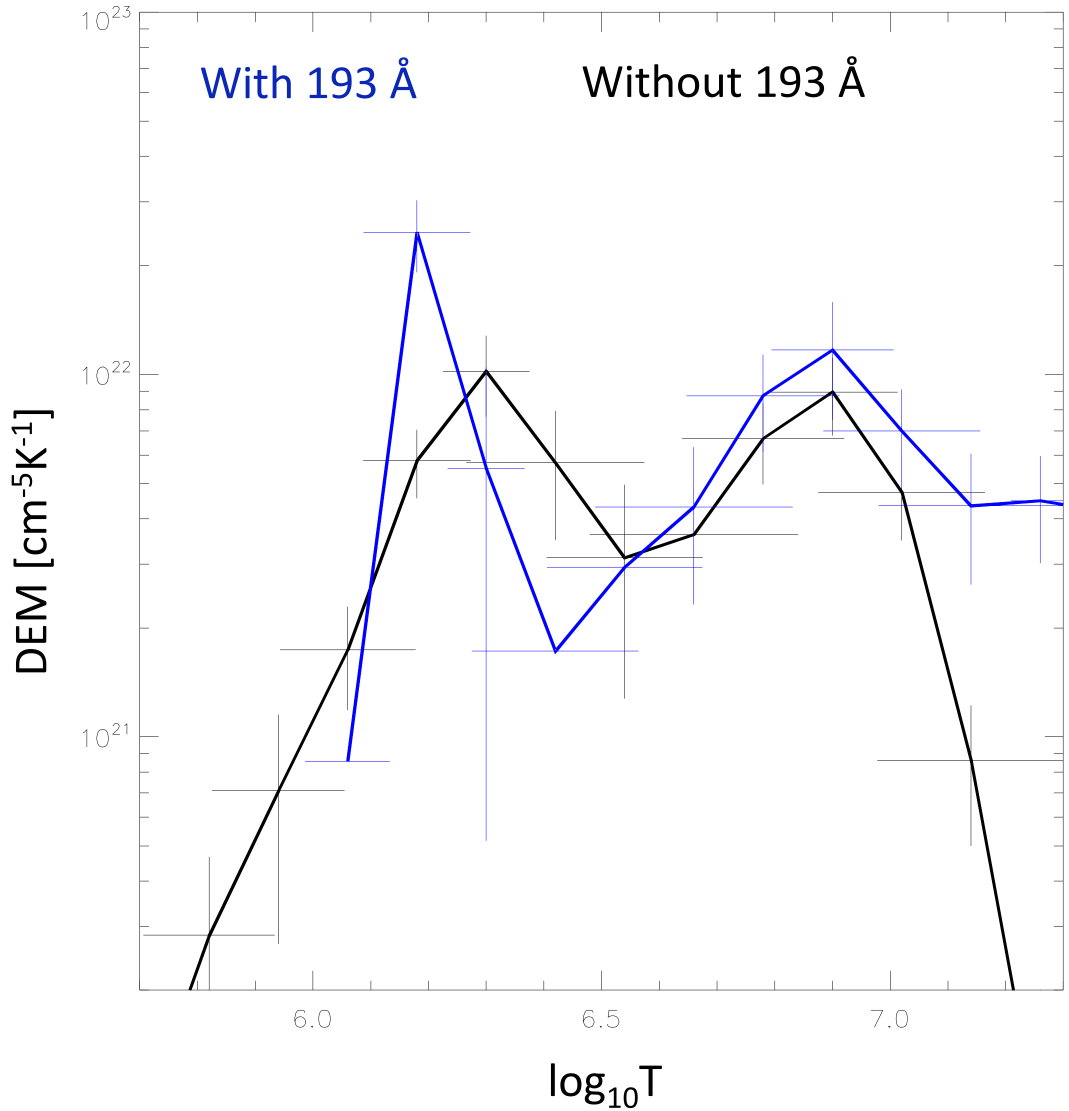
Saturation



2.0×10^4
1.5×10^4
1.0×10^4
5.0×10^3
0
AIA DN/s/px
94
131
193
171
335
211
304
Region 3
Region 2
Region 1
Region 4
0
5
10
15
20
HXR footpoint
Height [arcsec]
SXR coronal source

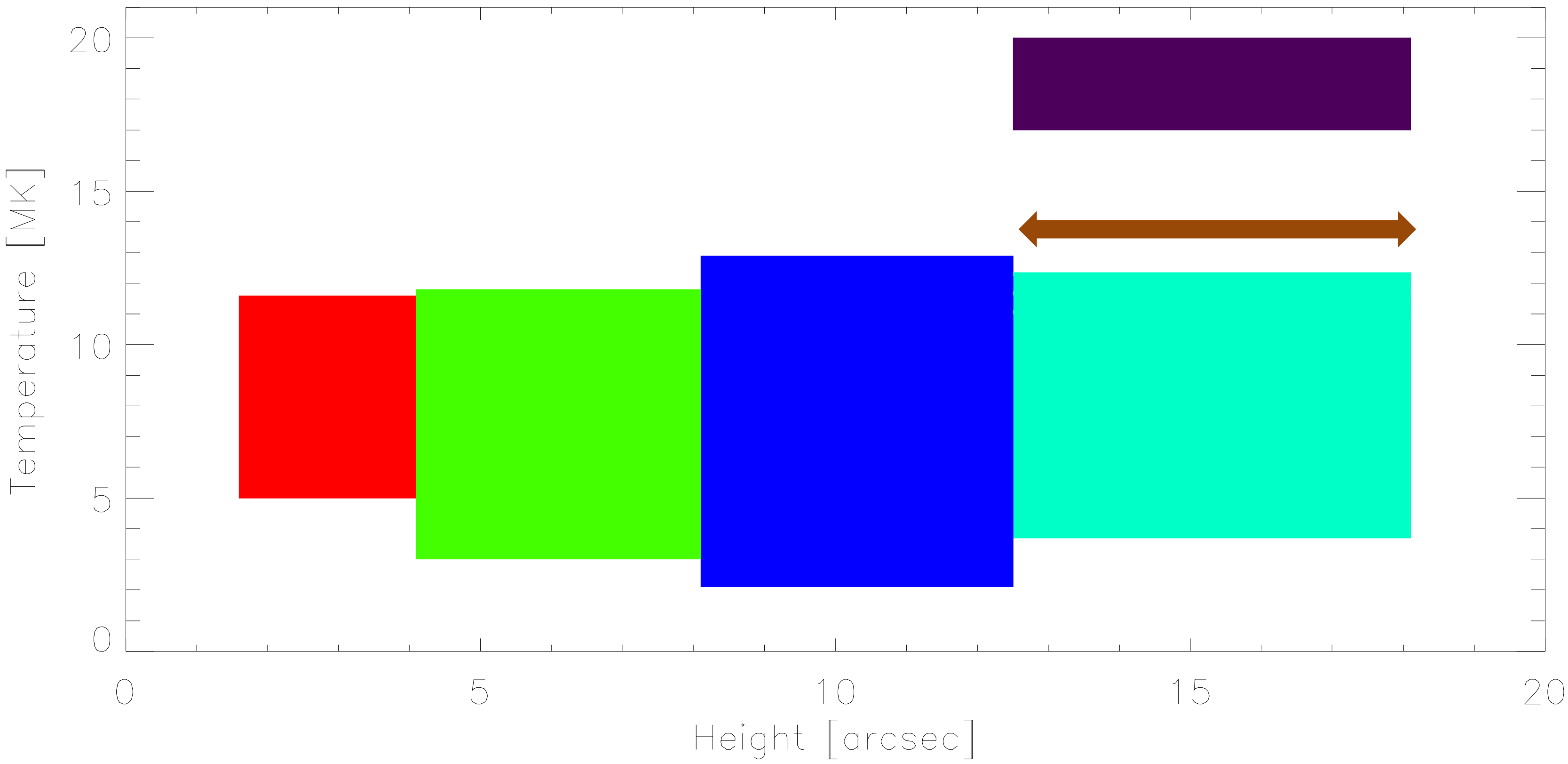


SDO AIA_2 193 07:30:09.440
290
280
270
260
250
Y (arcsecs)
−950
−940
−930
−920
−910
X (arcsecs)



With 193 Å
Without 193 Å
DEM [cm-5K-1]
log10T
10^23
10^22
10^21
6.0
6.5
7.0

Comparison of thermal parameters: temperature



Comparison of densities

- From total EM can calculate density: $n = \sqrt{\frac{EM}{V}}$ where $V=A^{3/2}$ in the case of RHESSI and $V=AL$ with L the line of sight for EUV observations (assume L = 3.6 Mm)

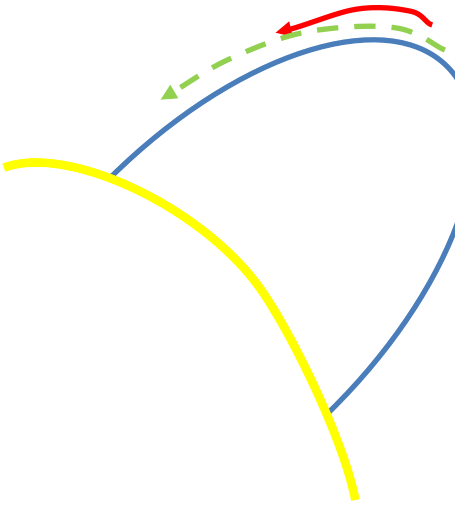
- Energy dependent position of HXR footpoints → chromospheric density (Battaglia et al. 2011, Kontar et al. 2010) and reference height of photosphere

  → can map x/y-positions to height

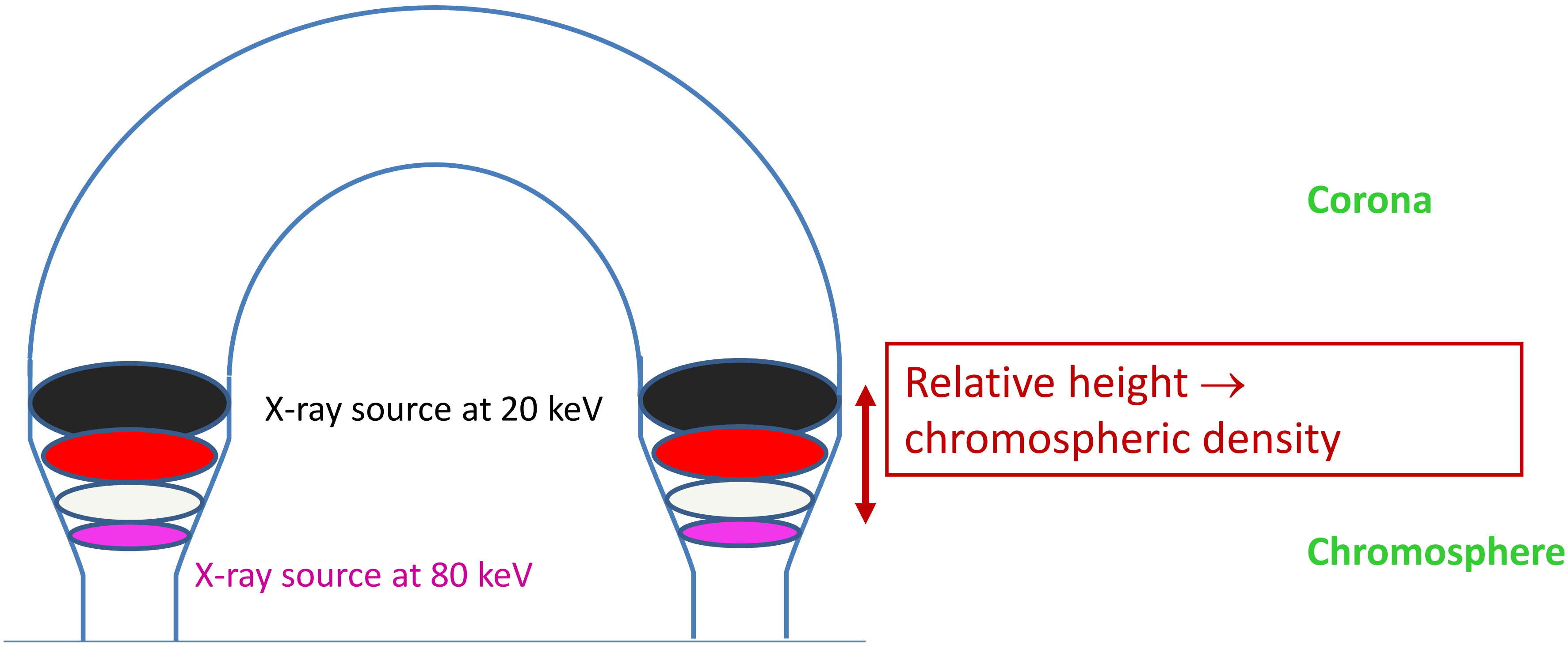
Energy dependent positions of HXR footpoints

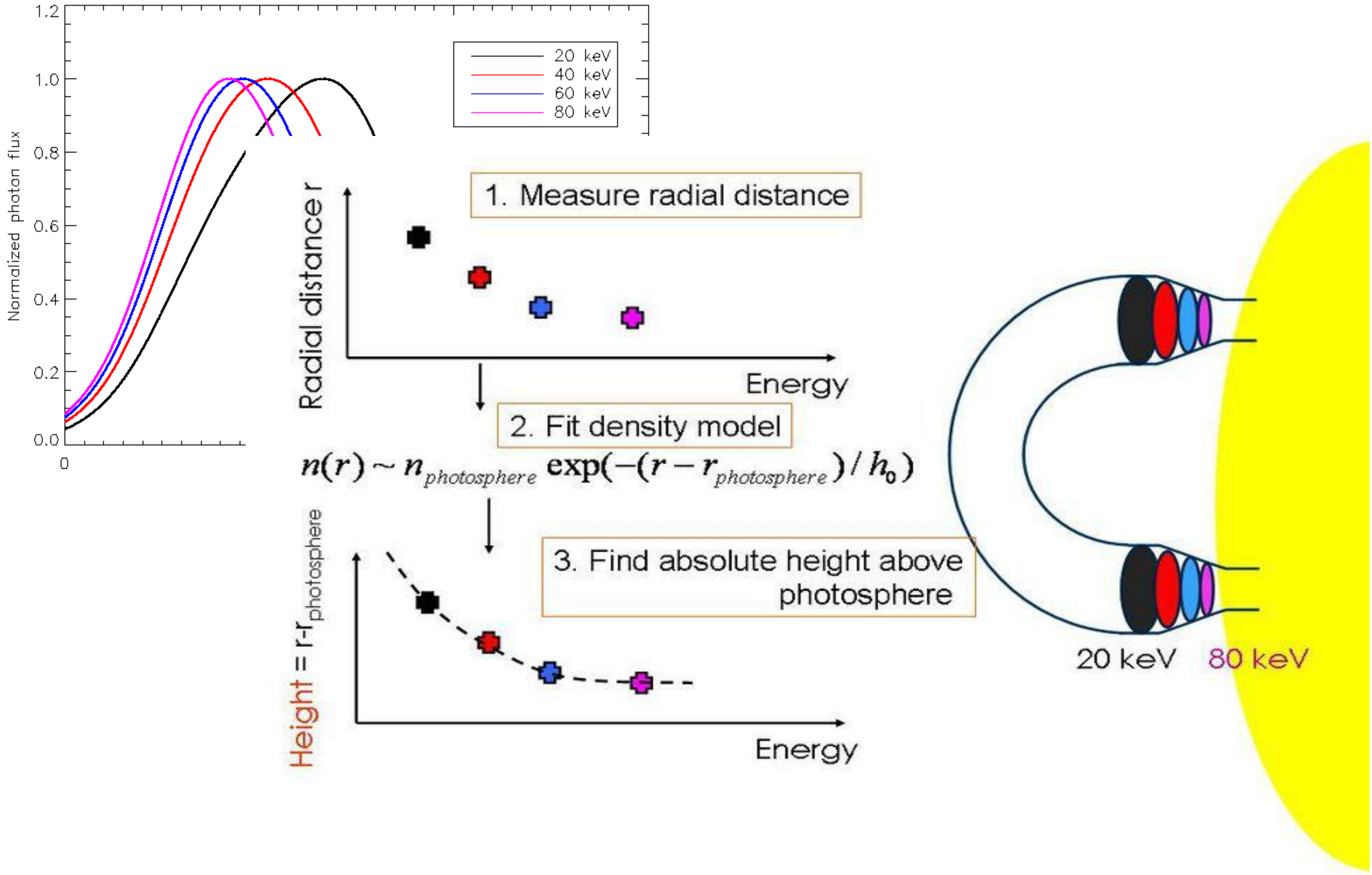
In the classical thick target theory (Brown 1971)

- Electrons suffer coulomb collisions with particles in the ambient plasma as they travel downward along the magnetic loop → energy loss and deflection
- Electrons with higher initial energy are stopped lower down in the target → this should be observable in X-rays
- Stopping depth depends on ambient plasma density



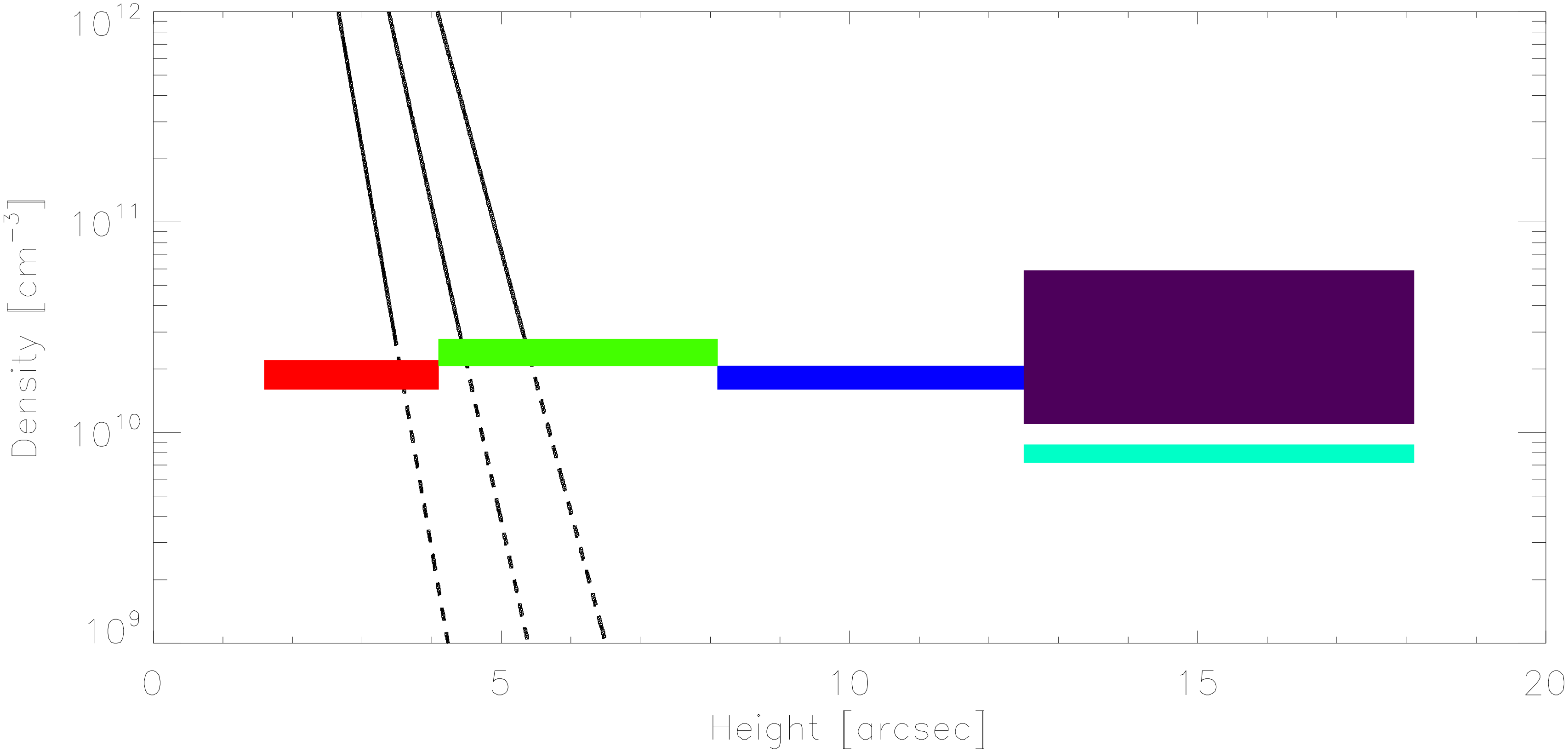
Simplistic view of a loop and X-ray source height





1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
Normalized photon flux
20 keV
40 keV
60 keV
80 keV
Radial distance r
Energy
1. Measure radial distance
2. Fit density model
$n(r) \sim n_{photosphere} \exp(-(r - r_{photosphere})/h_0)$
3. Find absolute height above photosphere
Height = r-r$_{photosphere}$
Energy
20 keV
80 keV

Comparison of thermal parameters: density



Conclusions

- Combining X-ray observations from RHESSI and EUV observations from AIA we can measure the thermal characteristics and the density of a flaring loop using two independent methods
- AIA DEMs almost always show two temperature components. The low temperature component can be attributed to line of sight effect
- The AIA EM is up to two orders of magnitude smaller than RHESSI and GOES in the analysed flare.
- Most likely explanation: Very hot temperature of the plasma at this stage which is above the main sensitivity range of AIA in combination with omitting 193 and 131 Å due to saturation