Spectroscopic investigation of very hot plasma in a quiescent off-limb active region: spatial and temporal properties

(submitted to ApJ)

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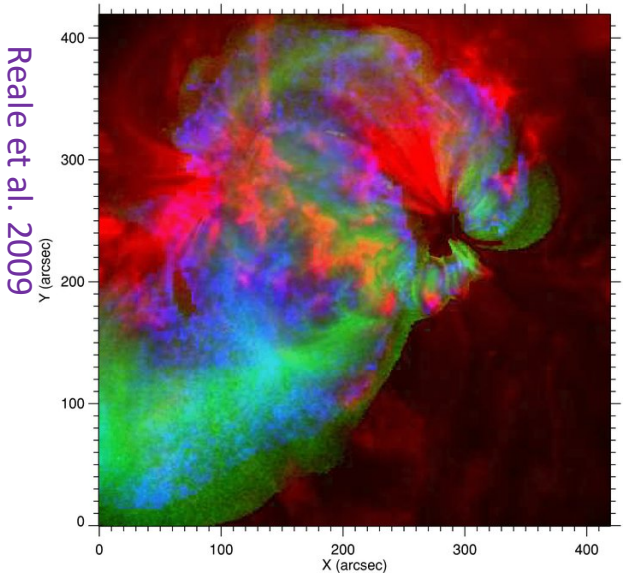
Understanding the heating mechanism in non flaring ARs



How: we provide spatial and temporal quantification of the EM from 3 to 10 MK

Why: It is the signature of the initial heating events. Predicted by the impulsive heating model but difficult to quantify.

What's new: Measured Fe XIX (~10 MK) in one off-limb AR

- 17h of continuous observations
- Deep exposures
- DEM/EM from Fe X – Fe XIX

Work outline

- The observations
- SUMER-AIA-EIS alignment
- Temporal variability of hot lines within the masks
- Spatial variability of hot lines on time-averaged spectra along the slit
- EIS radiometric calibrations (Warren ‘13 vs Del Zanna ‘13)
- SUMER Ca XIV 943.58 Å CHIANTI model
- SUMER-EIS cross calibration
- Thermal analysis (Loci EM, DEM, MCMC EM)
- Conclusions

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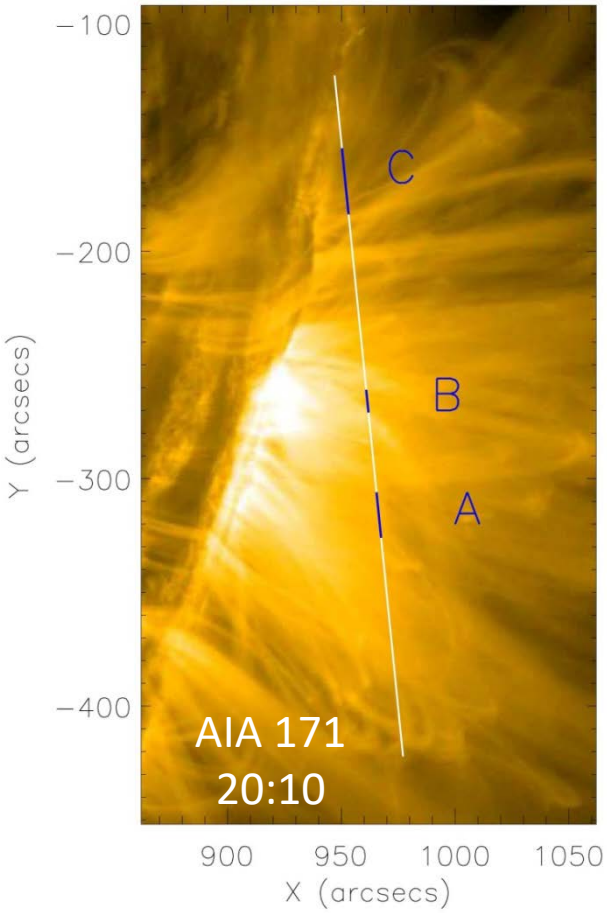
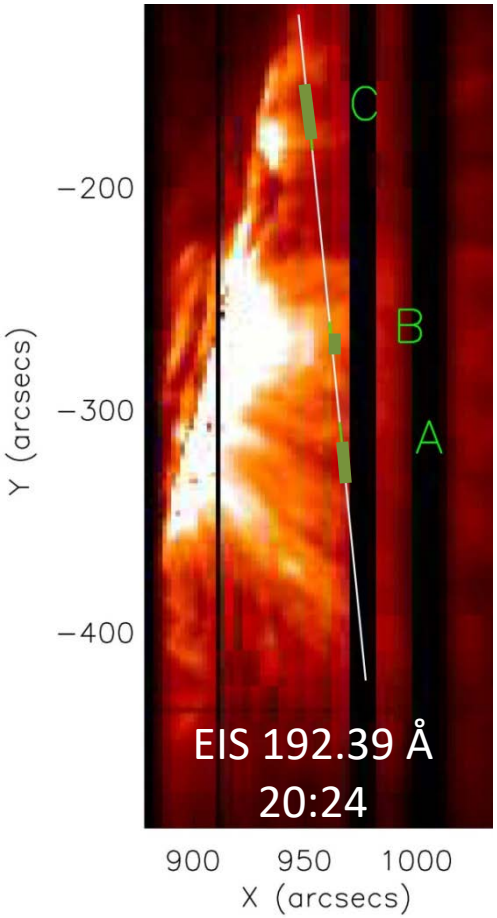
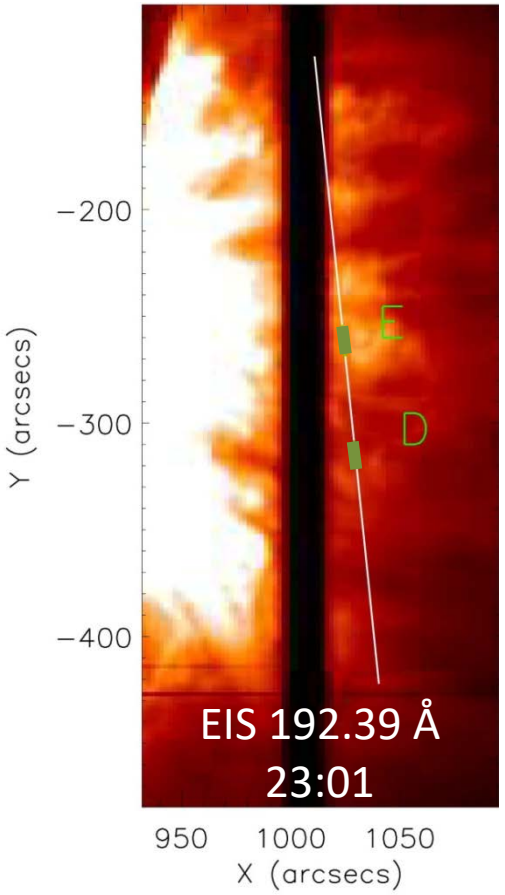
AR 11459 – 27/28 April 2012



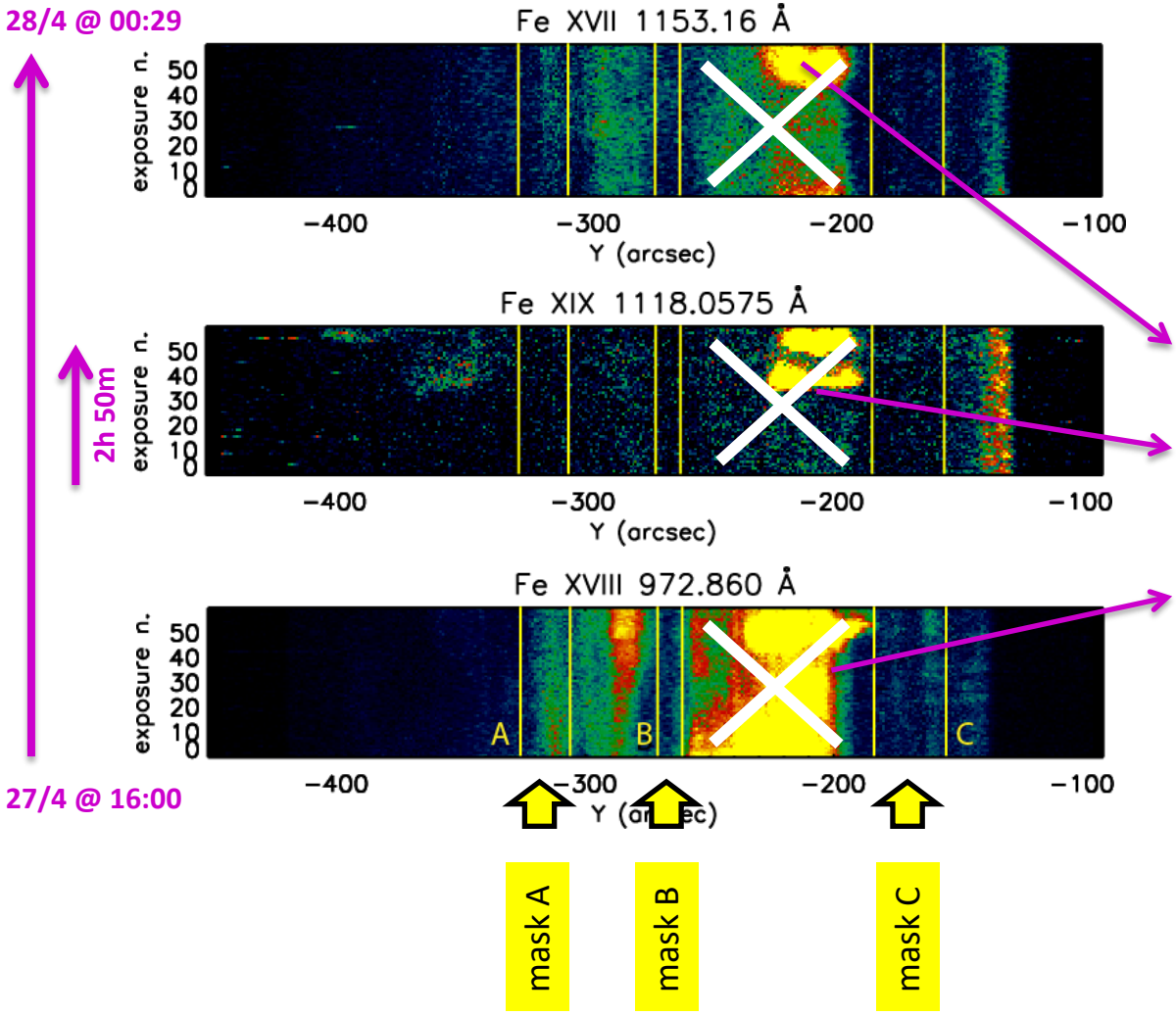




EIS: Fe X – XVI

SUMER: Fe XVII – XIX

Temporal variability in hot lines: SUMER



Data:

- Full temporal resolution
- Full spatial resolution

⬇

bad SNR for Fe XIX

⬇

Averaged spectra

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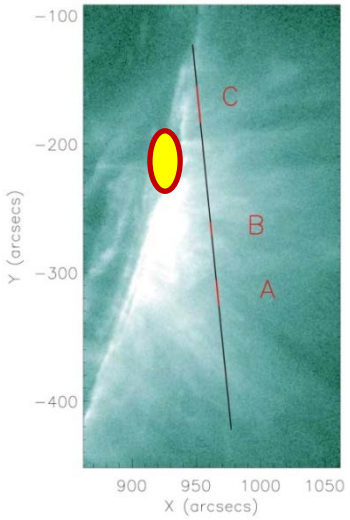
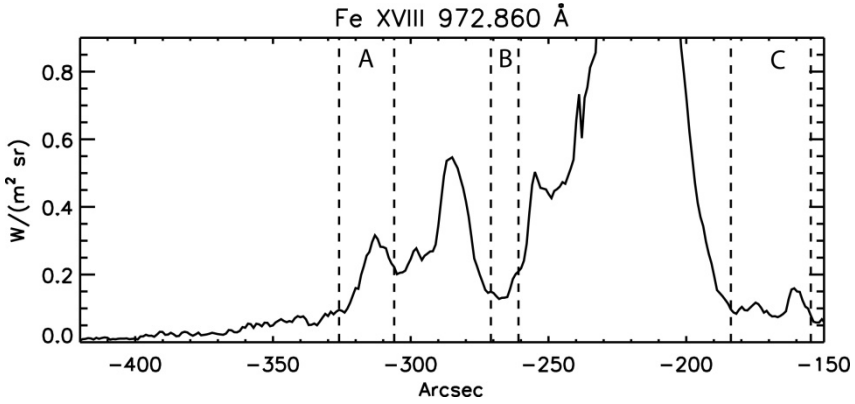


SUMER hot lines

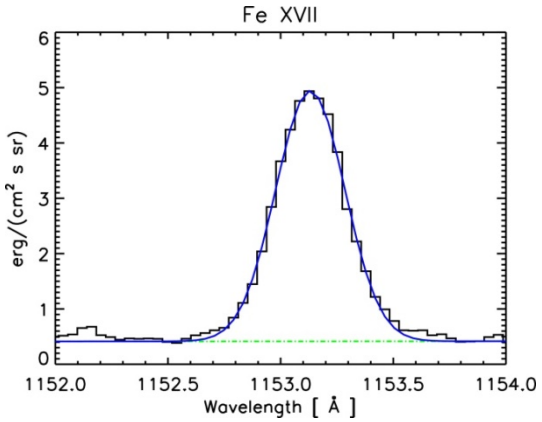


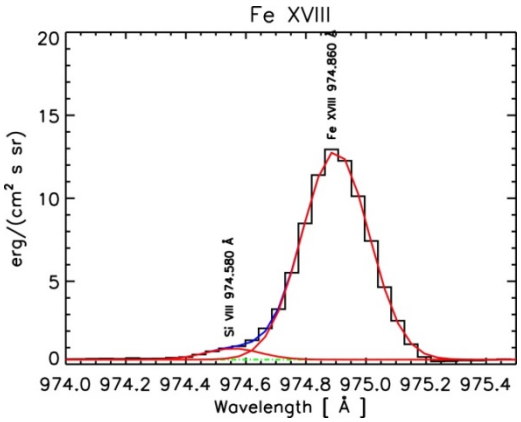
Intensity along the SUMER slit:
Consistency of the Fe XVII and Fe XVIII profiles (observed 7h apart)

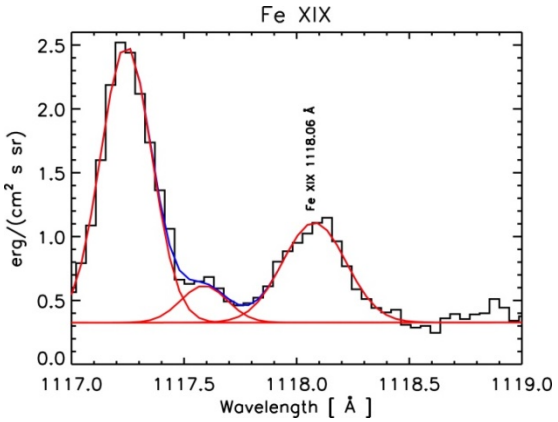
Temporal and spatial averaged spectra:

- Mask A and C (D, E): structured hot plasma with measured Fe XIX
- Mask B: background emission with no Fe XIX

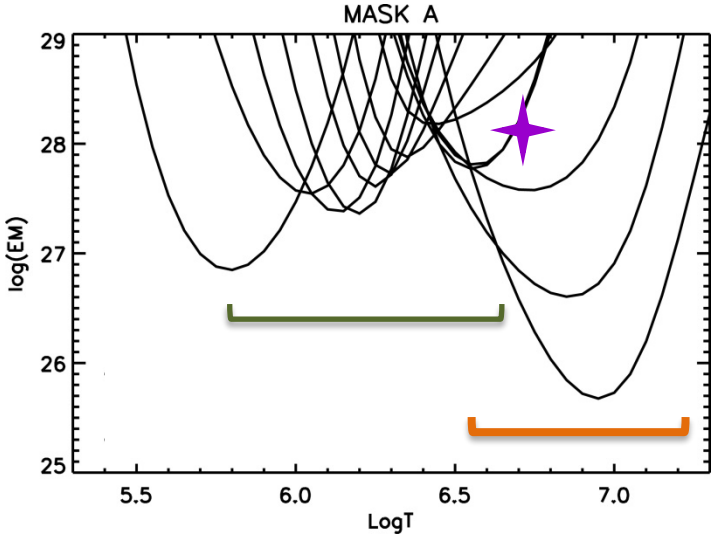
Mask A average spectra:

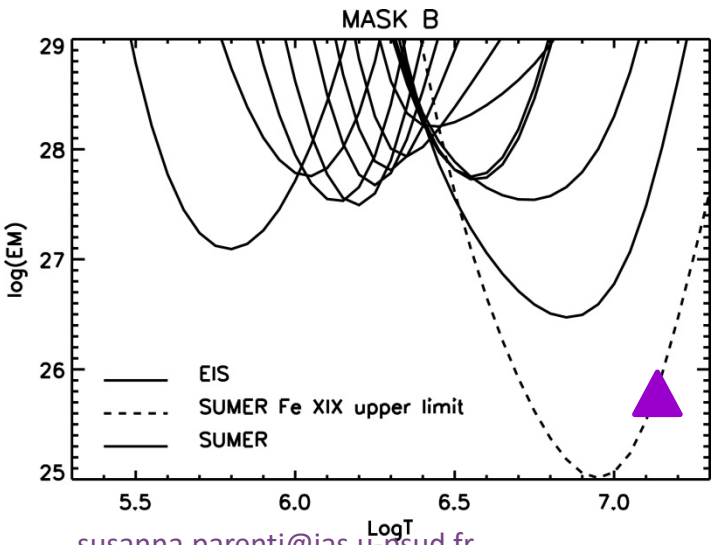






Emision Measure loci





EIS Fe X – XVI

SUMER Fe XVII – XIX

SUMER & EIS Ca XIV: cross-calibration

EIS Fe XXIII or SUMER Fe XIX upper limit

Result # 1

The loci are similar for all masks apart for mask B

Similar thermal structure everywhere apart from B.

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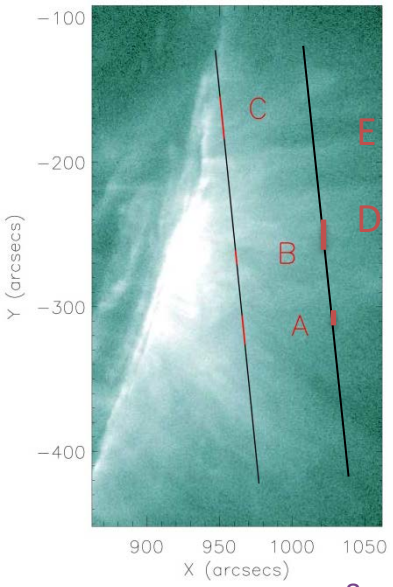
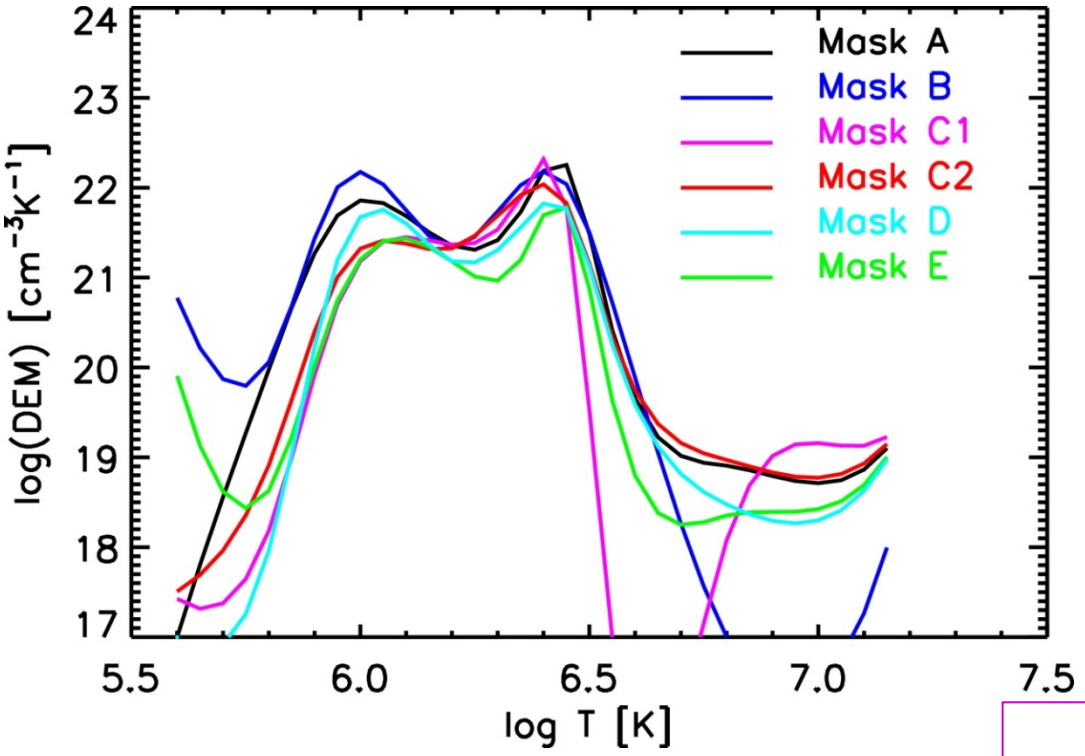


Differential Emission Measure



Imposed limits:

- I_{th}/I_{obs} within 25%
- Undetected flare lines: I_{obs} upper limits (3σ)
  - Fe XIX (B) $I_{th}/I_{obs} = 0.54$
  - Fe XXIII (A, C, D, E) $I_{th}/I_{obs} < 0.25$

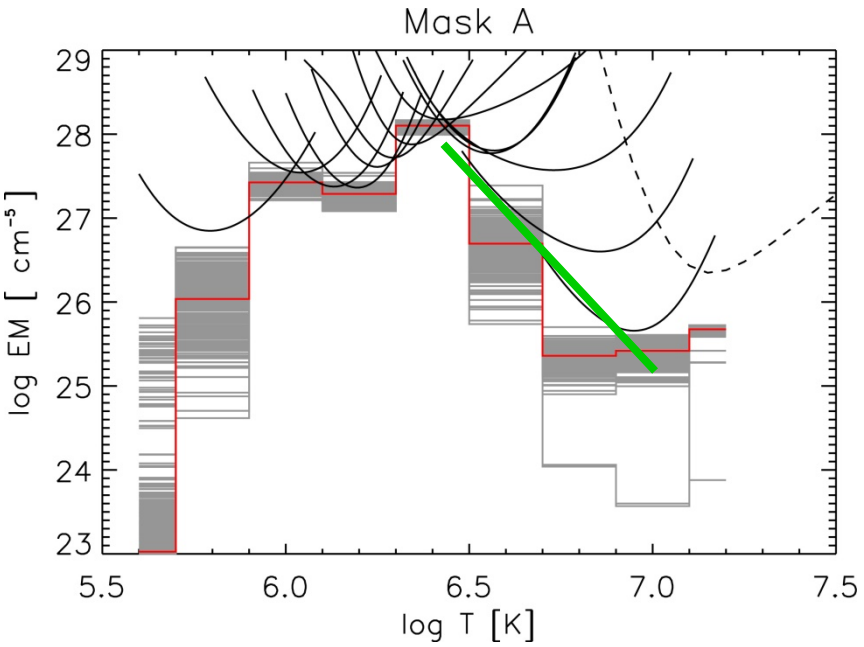
Results #2:

DEM (10 MK) ≤ 0.1 % DEM (2.5MK)

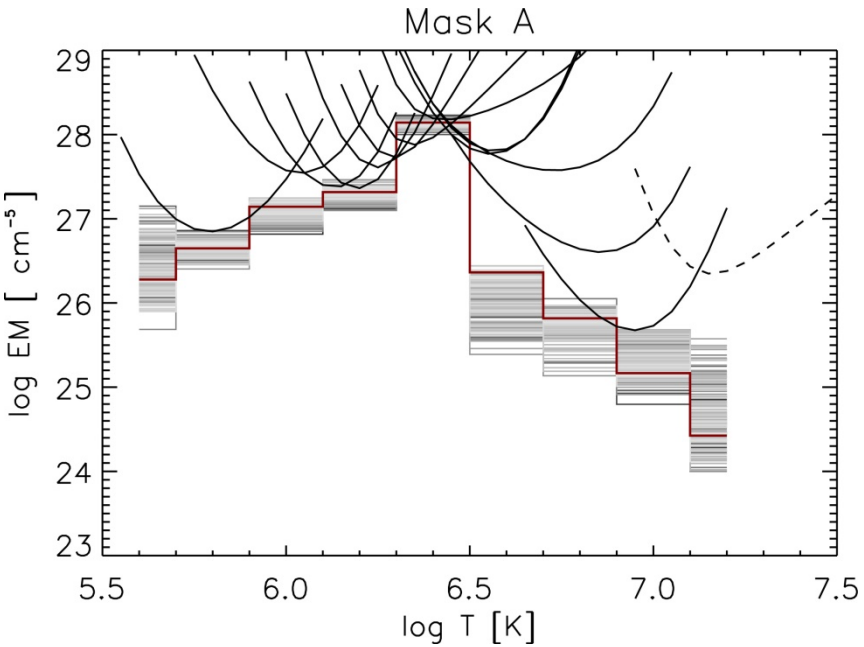
With measured Fe XIX

Emission Measure distribution

From DEM



MCMC



Tests:

- Two independent methods
- Temperature bin size
- Temperature interval

Results #3

- The 2 methods are consistent
- The hot EM needs further constraints
- $6.4 < \log T < 7$, $EM = T^{-\alpha}$ with $4 < \alpha < 5$

Conclusions

Thermal analysis results

- Persistent hot plasma (> 3MK) almost everywhere
- EM (10 MK) = 0.1 % EM (2.5MK)
- This ratio is constant over 17h (observation time).
- EM = $T^{-\alpha}$ above 3MK: $4 < \alpha < 5$ for the hottest regions. Shallower for off-limb regions?
- The results do not exclude a possible minor peak of the DEM at ~ 10MK
- New Ca XIV 943.59 Å atomic model
- SUMER – EIS intercalibration (Del Zanna and Warren EIS calibrations)

Implications

- Common heating process, also above the limb.
- The hot plasma is probably more concentrated low in the corona. (often 1% in on-disk AR)
- Temporal persistency
- Some dependence on the age of the AR? line of sight effect (loops footpoints)?
- We need to look at the X-ray data or more sensitive EUV instruments
- It will be included in the next CHIANTI