HEATING OF ACTIVE REGION CORE LOOPS BY NANOFLARES

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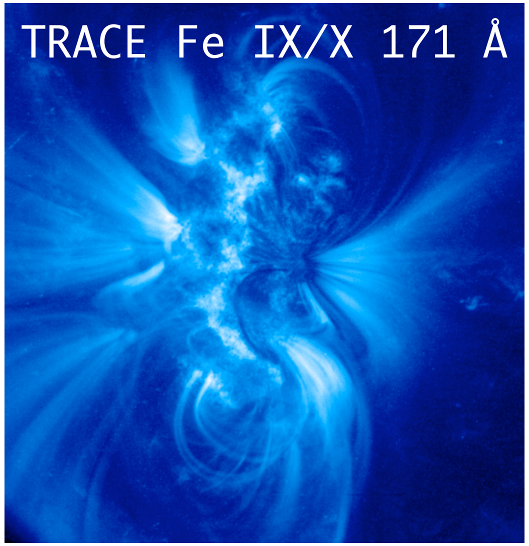
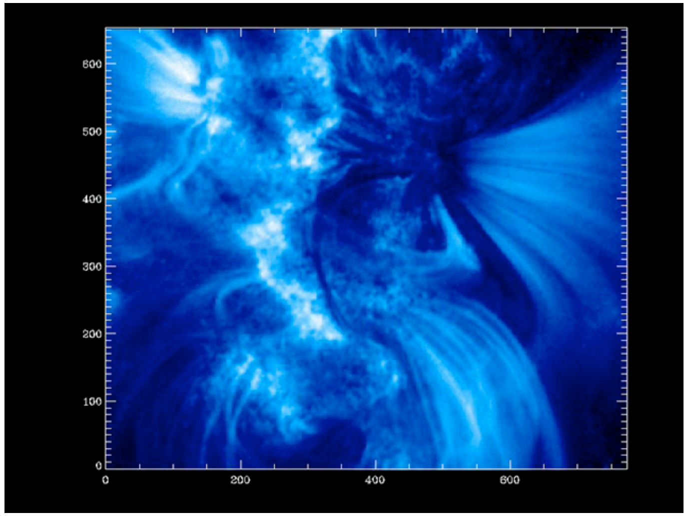
Active Region Moss

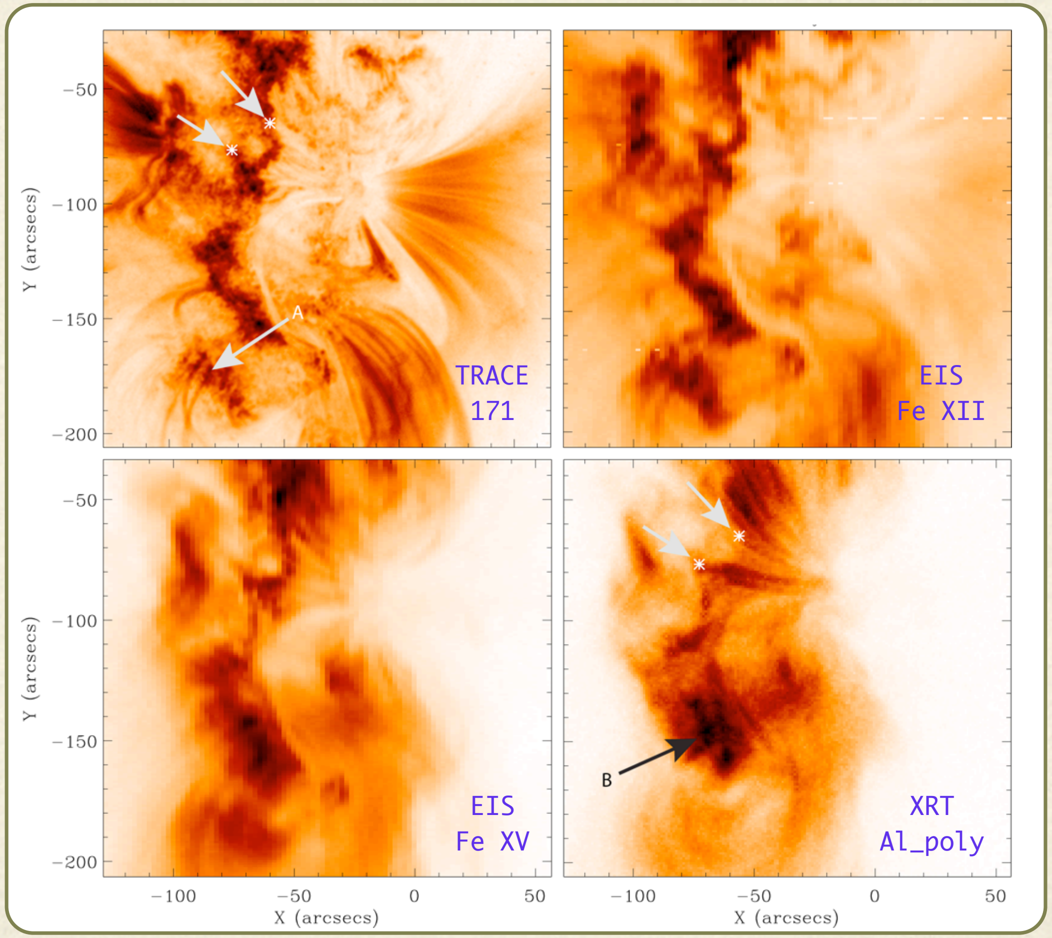


- Moss regions are bright, finely textured mottled, low lying emission above active region plage area, best seen in TRACE Fe IX/X 171 images (Schrijver et al 1999).



- Almost impossible to spatially resolve hot core loops.
- Moss regions are foot points of hot (3-5 MK) loops seen in core of active regions.

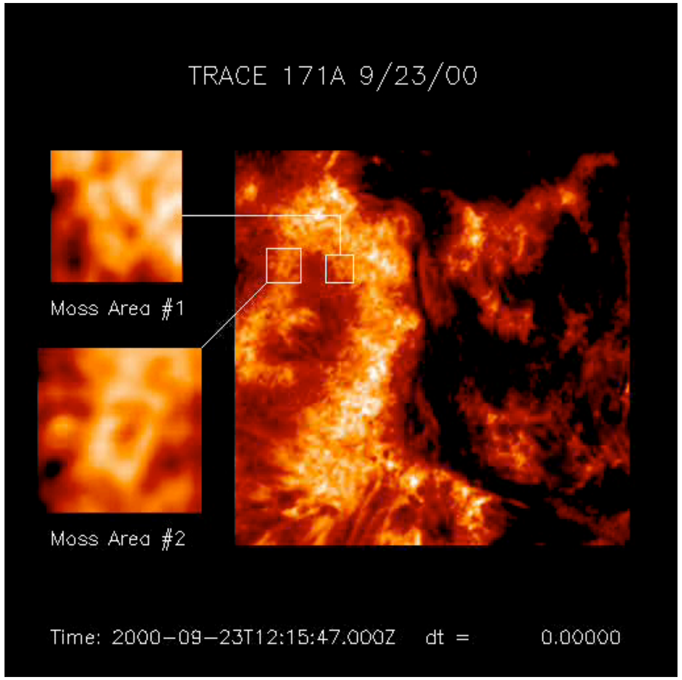
Active Region Moss



Tripathi, Mason, Del Zanna, Young 2010, A&A

Some results...

- Minimal variability in:
  - **moss intensities (~10%) averaged** over several TRACE pixels (Antiochos et al. 2003).
  - **Doppler shift and line width** (Brooks and Warren 2009).
  - **density and temperature** structure (Tripathi et al. 2010).
- Predicted intensities using **steady heating** match quite well with observed intensities **IF** an **expansion at the footpoints of loops** are considered (Warren et al. 2010).



Antiochos et al. 2003

Moss is time variable on a small scale. However global structure remains unchanged.

- These observations provide compelling evidence that **heating is steady**, but **only if** plasma **does not** have **unresolved structures.**

- Measurements suggest that **there are unresolved plasma structures**.

- We explore **Emission Measure (EM)** distribution in moss regions. Since these are the **footpoints of the hot loops**, the EM(T) is determined largely by variation of temperature along strands.

- We compare the **observed** EM(T) with **theoretical** EM(T) for different scenarios to gain some insight into the heating of hot core loops.

Transition Region DEM

Klimchuk et al. (2008) derived DEM(T) for three limiting cases:

- **Strong evaporation:** the heat flux from the corona far exceeds the radiative losses from the transition region. The energy balance is then between **thermal conduction heating and enthalpy cooling.**
- **Strong condensation:** the heat flux from the corona much less than the radiative cooling. The energy balance is then between **enthalpy heating and radiative cooling.**
- **Static Equilibrium:** the **heat flux from the corona** very nearly balances the **radiative losses from the transition region**.

Transition Region EM(T)

$$EM_{se} \approx \; ln(10) \; \left(\frac{\kappa_0}{14}\right)^{1/2} \frac{\bar{P} \; T^{3/4}}{k \; \Lambda(T)^{1/2}} \; ... \; static \; equilibrium$$

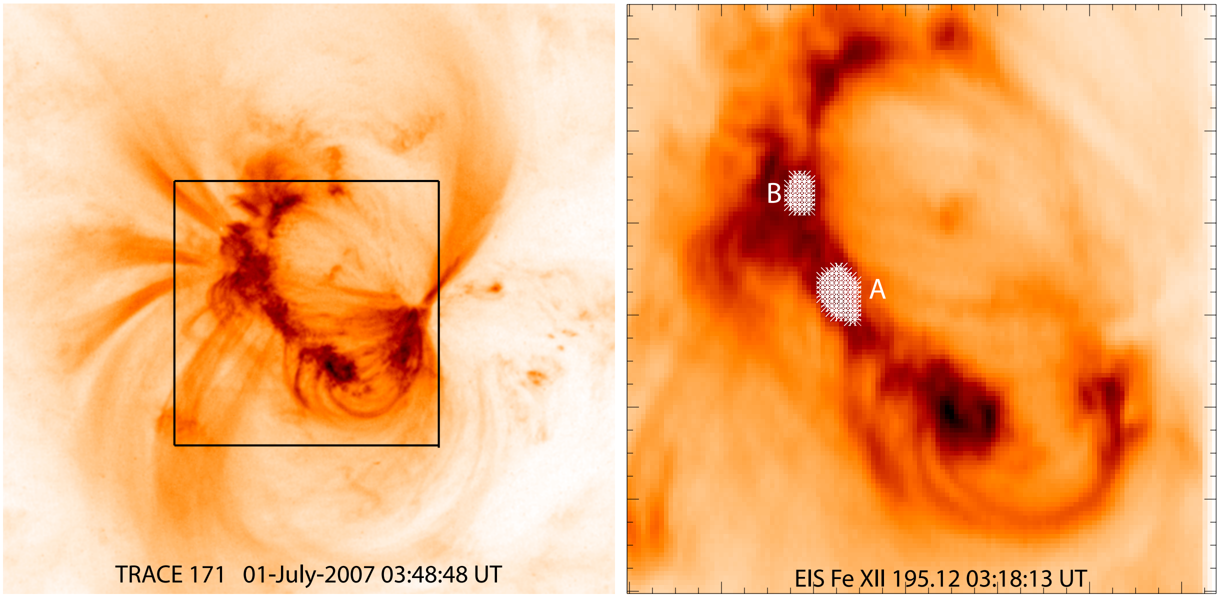
$$EM_{con} \approx - \; ln(10) \; \frac{5 \; k \; J_0 \; T}{\Lambda(T)} \; ... \; strong \; condensation$$

$$EM_{ev} \approx \frac{ln(10)}{20} \; \frac{\kappa_0}{k^3} \; \frac{\bar{P}^2 \; T^{1/2}}{J_0} \; ... \; strong \; evaporation$$

$\mathbf{k_0}$ = 1.6 x 10^{-6} CGS
k = Boltzmann's constant
T =Temperature
J0 = mass flux = **n v**
n = electron number density
v = plasma flow speed
Λ(T) = Optically thin radiative loss function (from CHIANTI v 6.0)

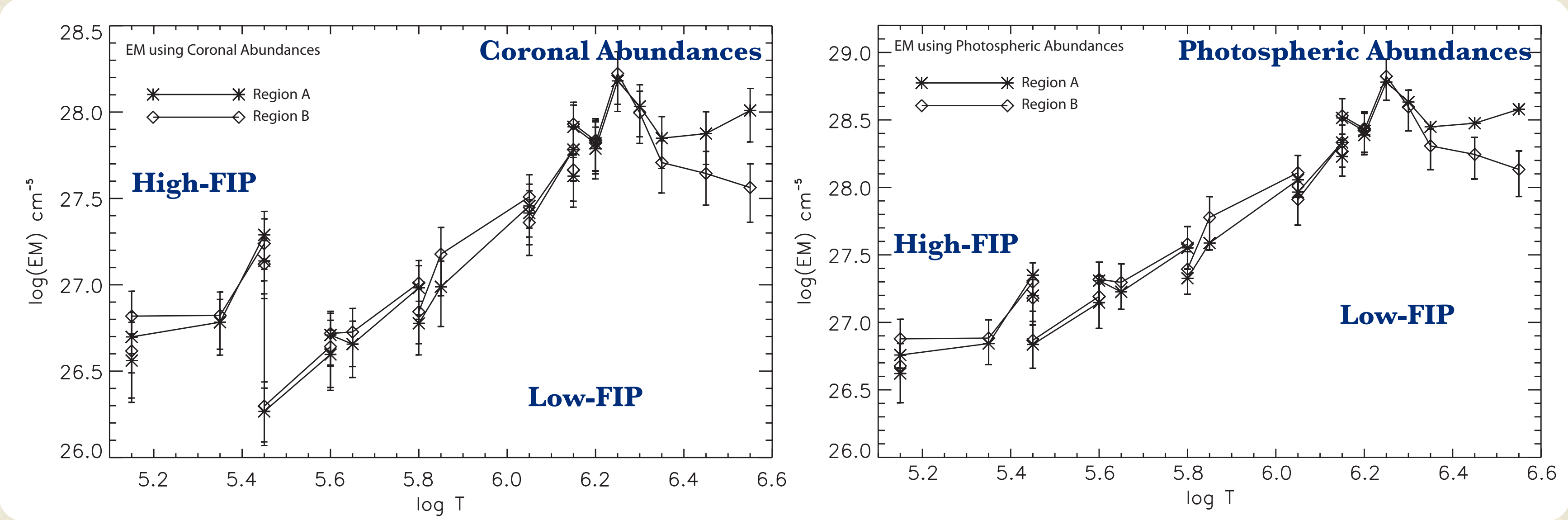
- Expressions provide emission measure curves for **individual strands.**
- We have considered average **pressure** and **mass flux** (J0) as arbitrary constants.
- We have restricted ourselves only with **temperature dependance** of the emission measure curves.

Hinode/EIS Observations



- Date: 01-Jul-2007, Full EIS Spectrum [170-210 Å, 250-190 Å]
- Exposure time: 25 sec, 1 arc sec slit
- FOV: 128” x 128”

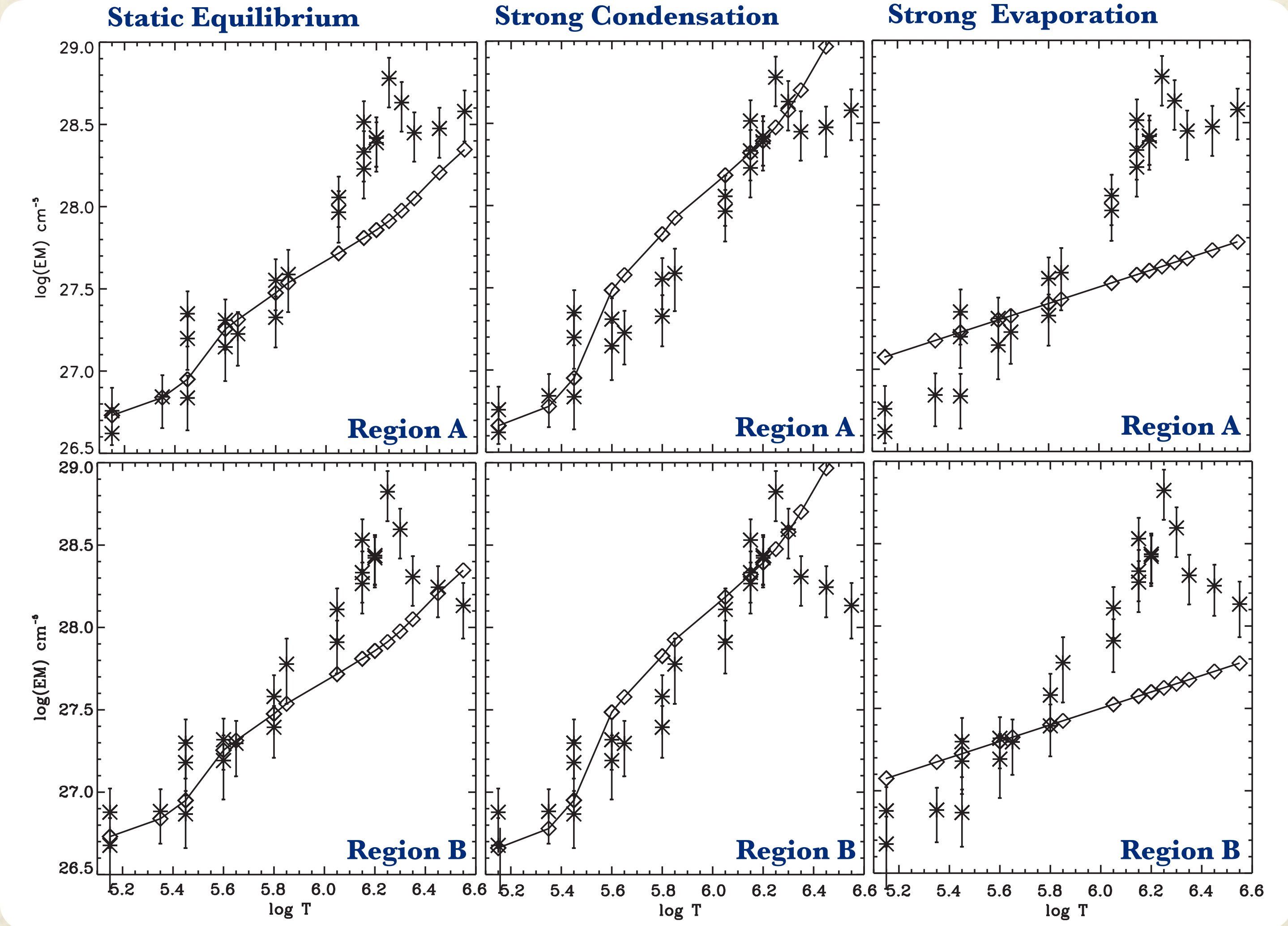
Observed EM(T)



- The EM(T) for two difference moss regions are **strikingly similar**.
- The EMs obtained using **photospheric abundances** are consistent for different ions.

Observed vs Theoretical EM(T)

EM curves obtained using photospheric abundances.



Conclusions

- The EM(T) distribution for two different regions are **strikingly similar.**
- The EMs obtained using **photospheric abundances** are consistent for different ions and show a **monotonically increasing** trend from log T = 5.15 - 6.3.
- The **EM for strong condensation** best reproduce the observations supporting the idea that hot loops seen in the core of active regions are **heated by nanoflares**.

Tripathi, D., Mason, H.E., Klimchuk, J. A., 2010, to appear in The Astrophysical Journal