New Instruments to Isolate the Coronal Heating Mechanism

Dr. Amy Winebarger, NASA MSFC

with contributions from the Hi-C, MaGIXS, and CLASP teams

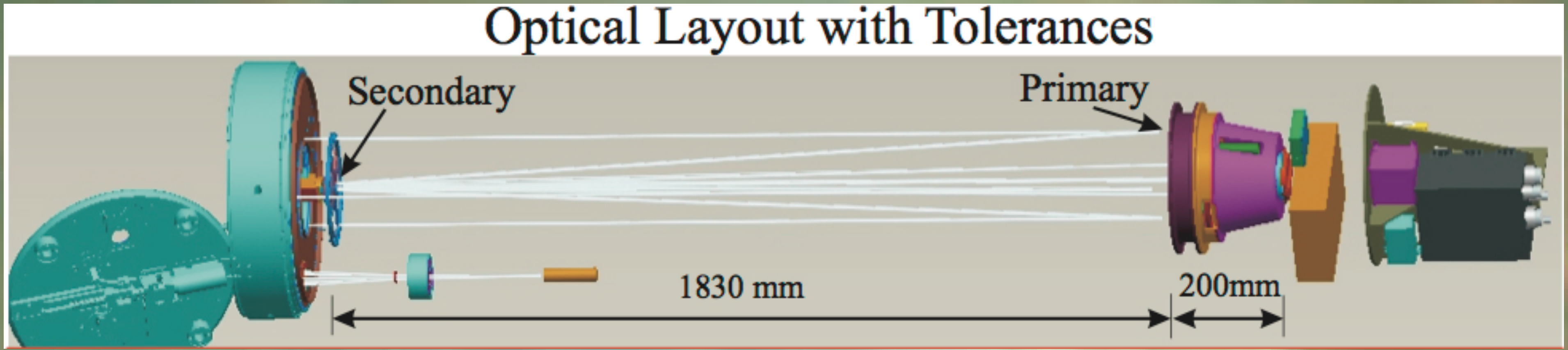
Why so slow?

Coronal heating has been a scientific goal of many of the instruments built in the last three decades. Why is still an open question?

- Coronal heating happens at smaller spatial scales than currently resolved **Hi-C**
- The clues of coronal heating are at higher or lower temperatures are easily sampled by current instruments **Hi-C + IRIS and MaGIXS**
- Energy storage and release are more easily detected in the chromospheric magnetic field

CLASP

High-Resolution Coronal Imager (Hi-C)



Hi-C flew on July 11, 2012.
Hi-C is proposed to fly again summer 2015 (in collaboration with IRIS)

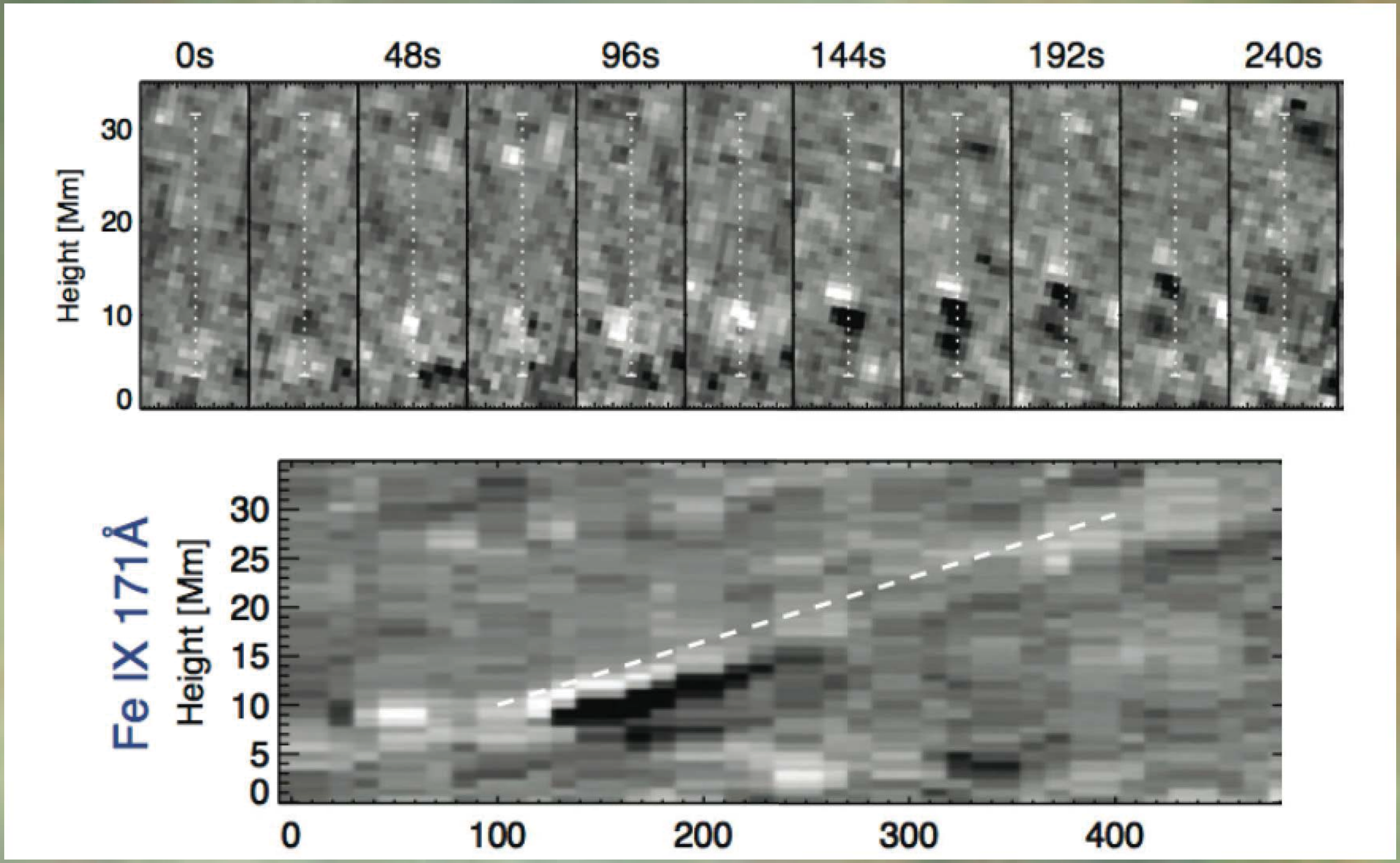
Two changes:
193 Å -> 174 Å
Low noise camera

Chromosphere-Coronal Connection

- There is definitely a chromospheric counterpart to coronal loops
- There may be a coronal counterpart to chromospheric structures
- Where is it? Why is it so hard to find?

The goal of the second Hi-C flight, proposed for summer 2015, is to look for this connection in the two most obvious places:
Type 2 spicules and active regions cores.

Type 2 Spicules – Origins of Hot Plasma in Corona?

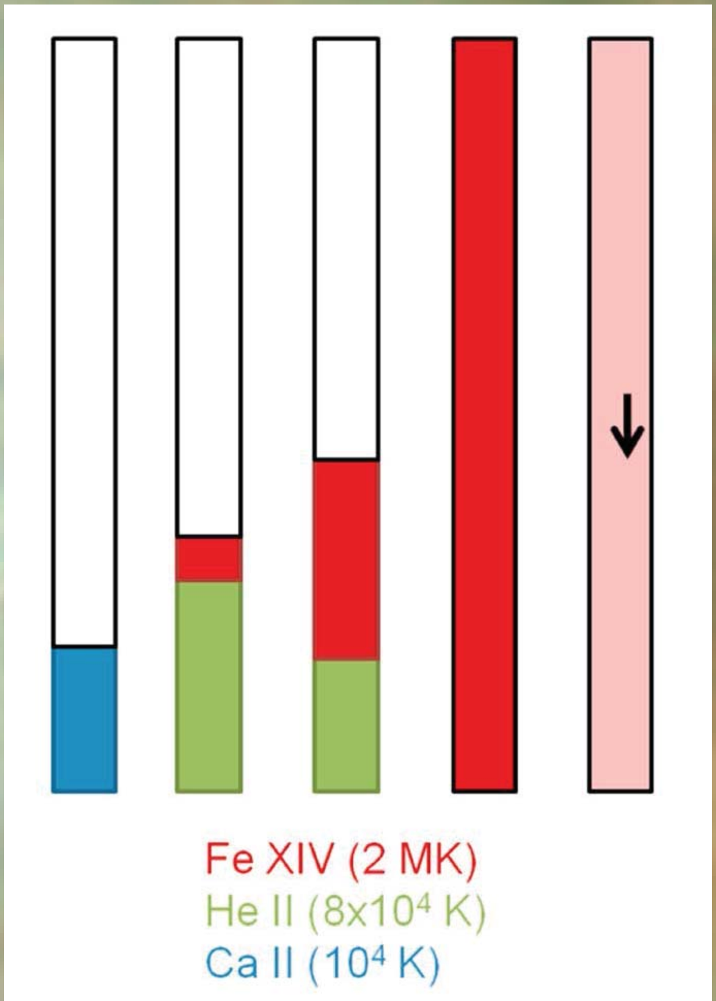


De Pontieu et al., 2011, Science, 6013, 55

Type 2 Spicules – Origins of Hot Plasma in Corona?

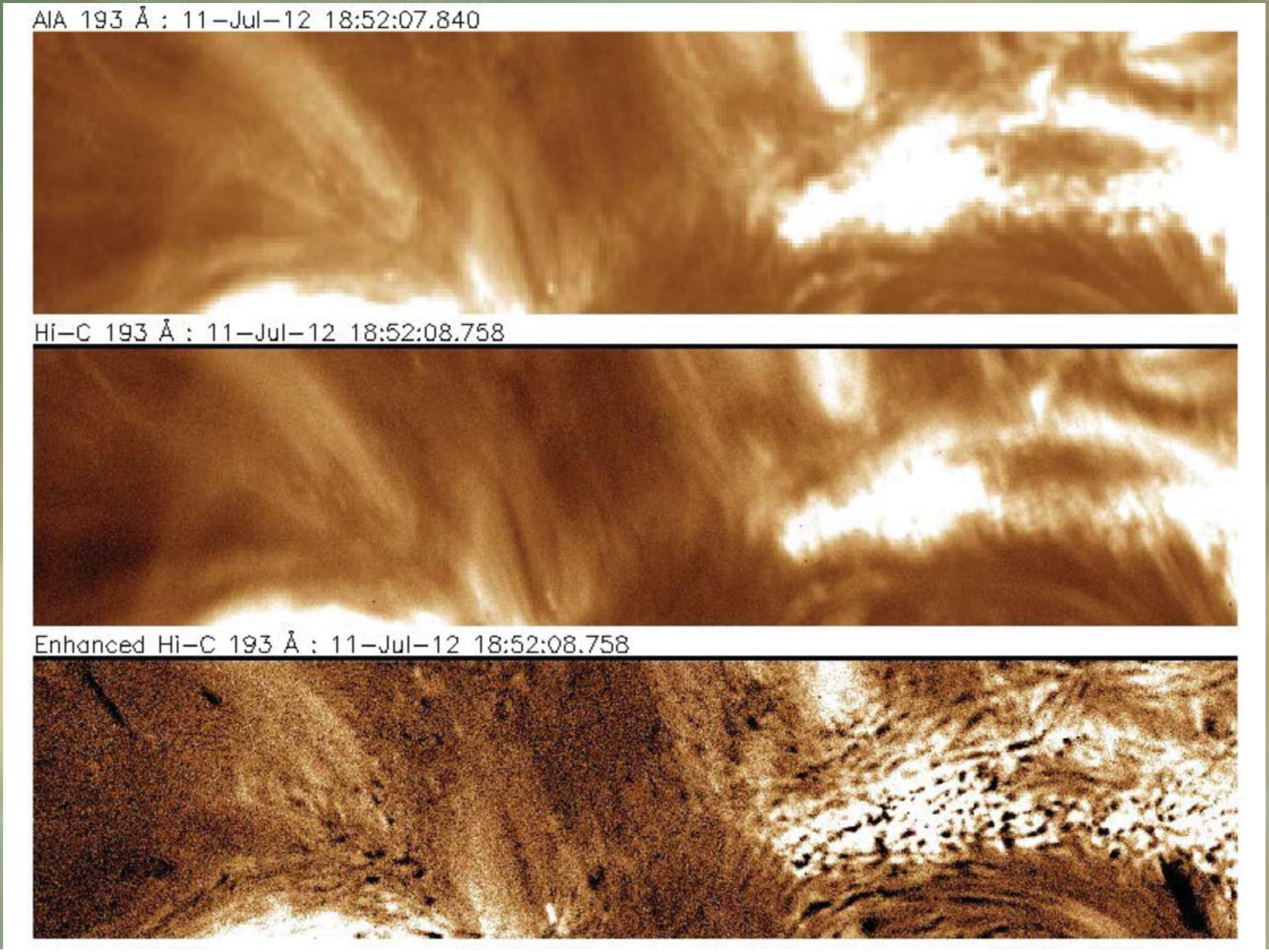
Madjarska et al. (2011, A&A, 532, L1) examined 3 large Type II spicules with SUMER and EIS and find no evidence for heating to coronal emission.

They suggest the AIA 171 signature is from TR lines in the passband.

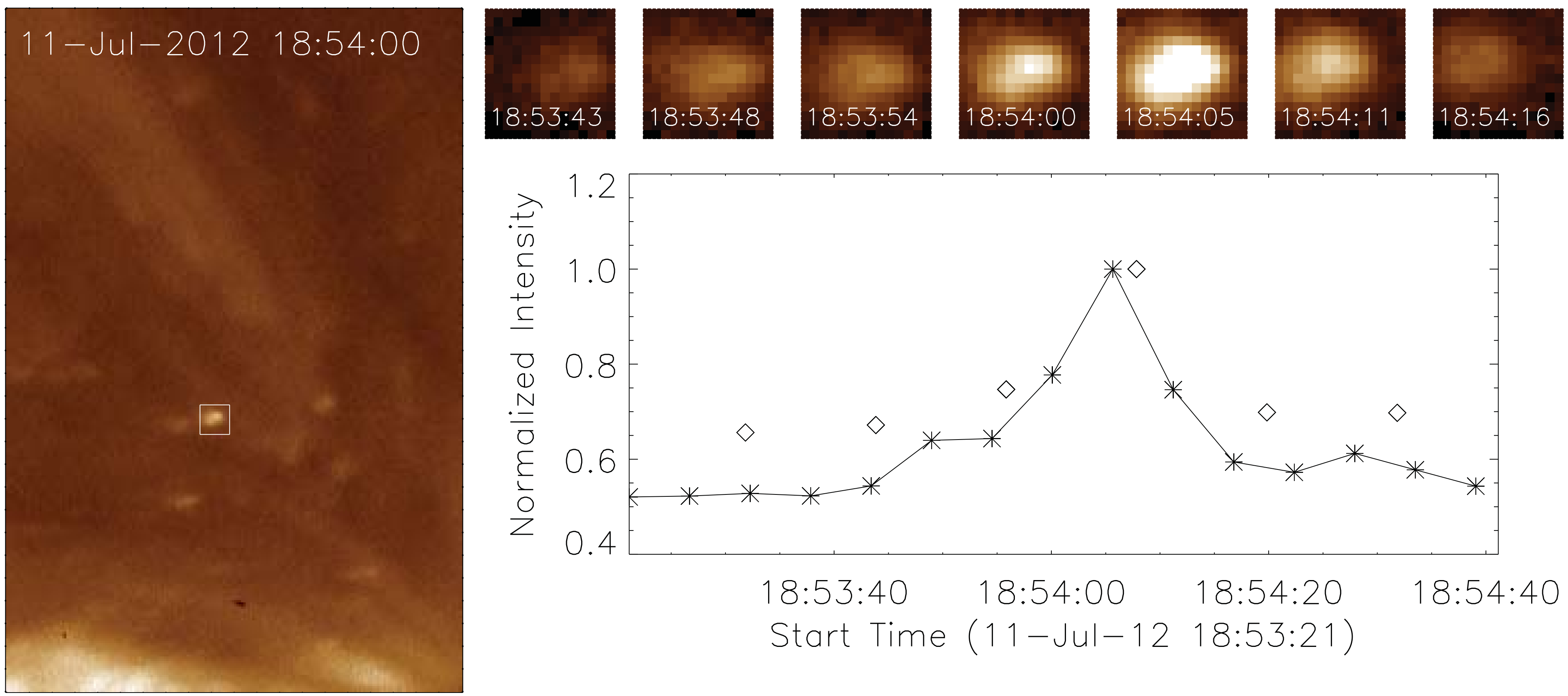


Klimchuk, 2012, JGRA, 117
Klimchuk & Bradshaw, 2014, ApJ, 791, 60

Type 2 Spicules – Observed in Hi-C 1?



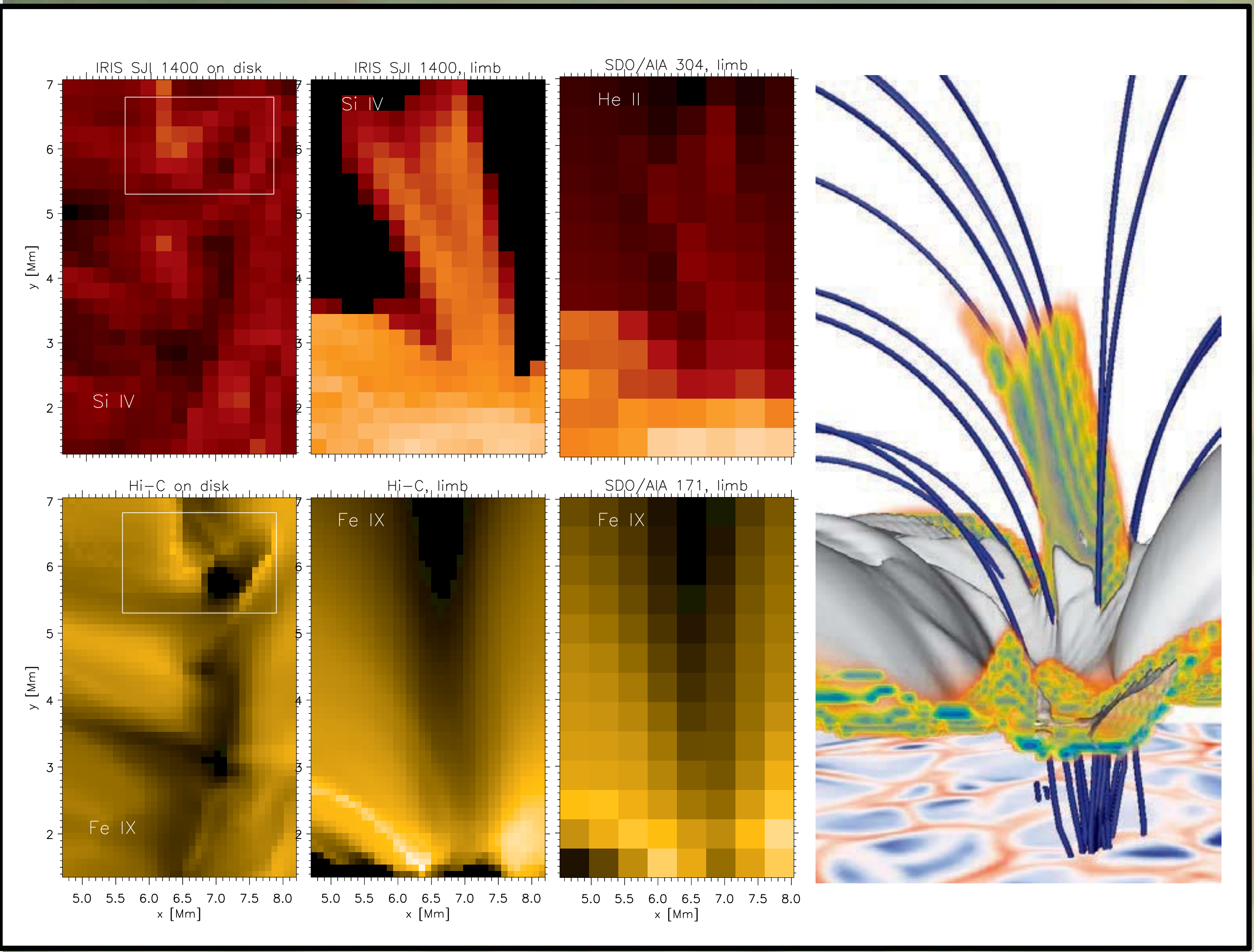
Type 2 Spicules – Observed in Hi-C 1?



Hi-C may have observed the coronal counterpart to Type 2 spicules. Without supporting observations, we can't be sure.

Regnier et al., 2014, ApJ, 784, 134

Hi-C Flight 2



- Hi-C will fly with IRIS, trace spicules through TR.
- Hi-C will have 174 Å passband.
- IRIS O IV spectral lines will help disambiguate the temperature of the Hi-C data.

Martinez-Sykora et al., 2013, ApJ, 771, 66

Where is the chromosphere of active region cores?

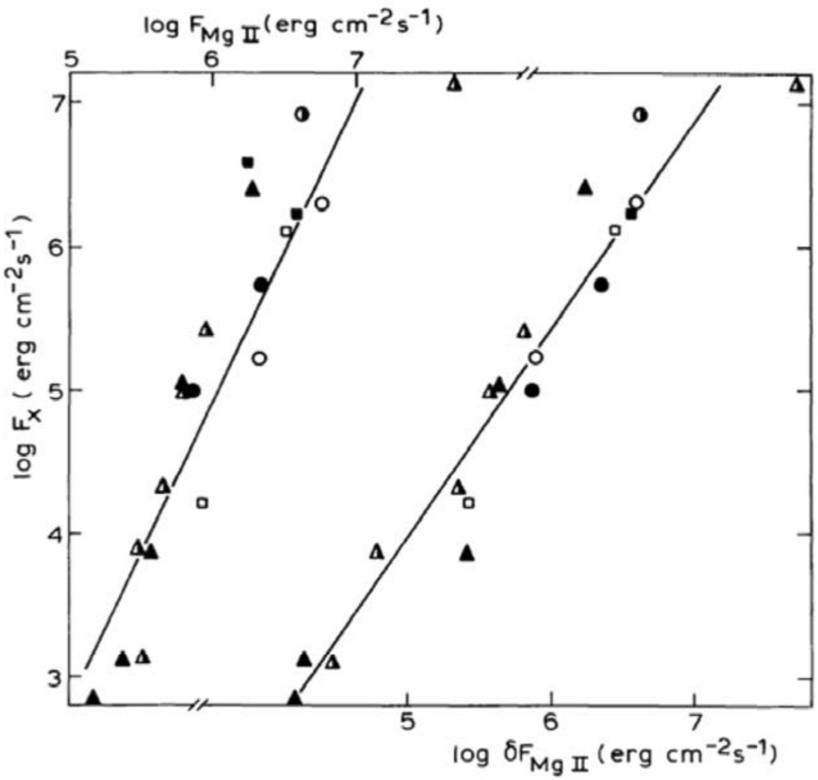
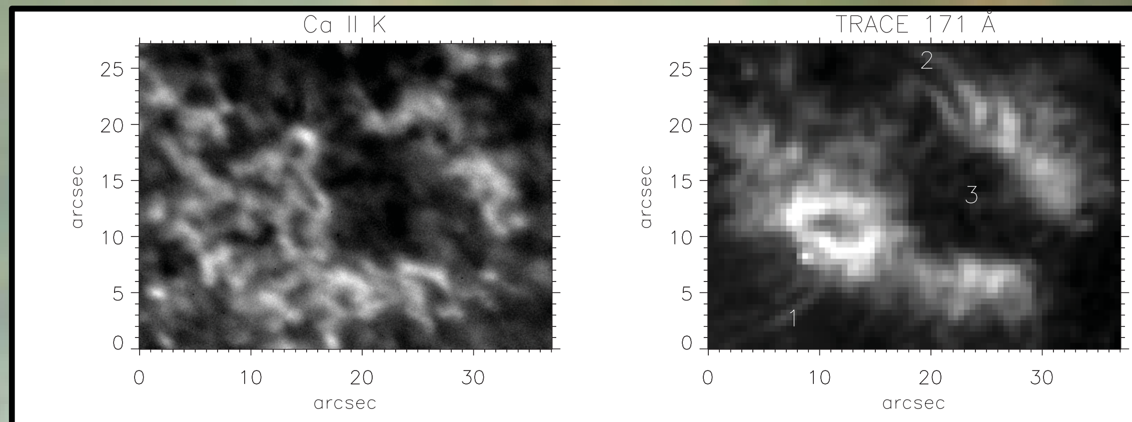


Fig. 5. Soft X-ray flux density F_X against Mg II h + k flux density $F_{Mg\,II}$ (left), and against the excess flux density $\delta F_{Mg\,II} = F_{Mg\,II} - \phi_{Mg\,II}$, $\phi_{Mg\,II}$ as in Table 2. Symbols as in Fig. 3

Schrijver, 1987, A&A, 172, 111

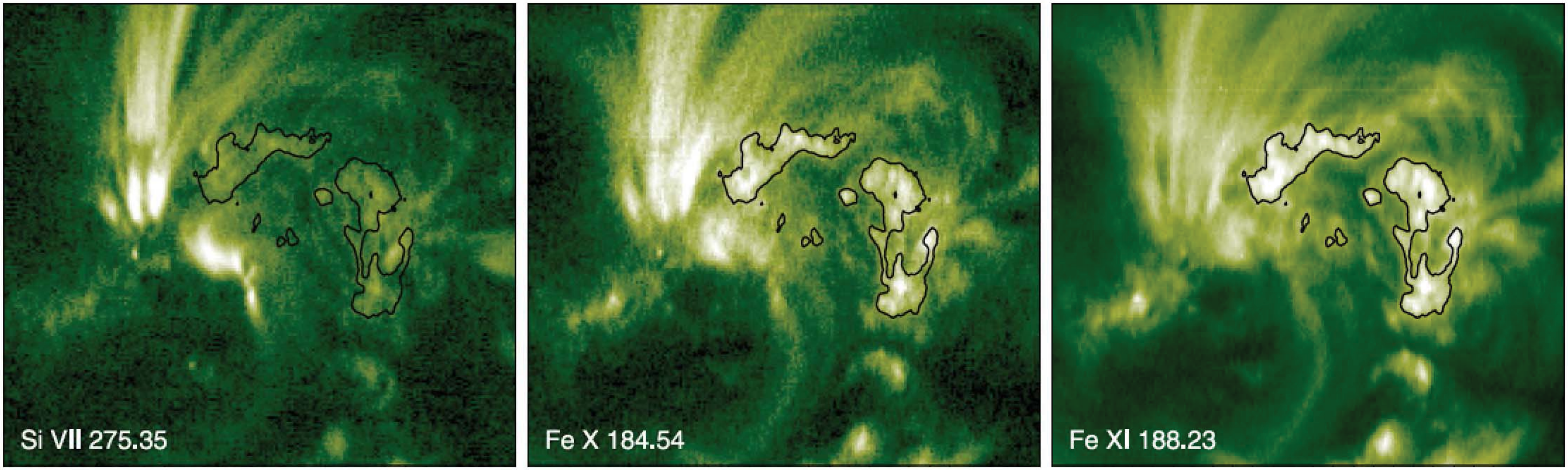


De Pontieu et al., 2003, ApJ, 590, 502

There is a lack of correlation between photosphere and upper transition region. Where do the hot loops "terminate"?

On global scales, there is a correlation between chromospheric and coronal emission.

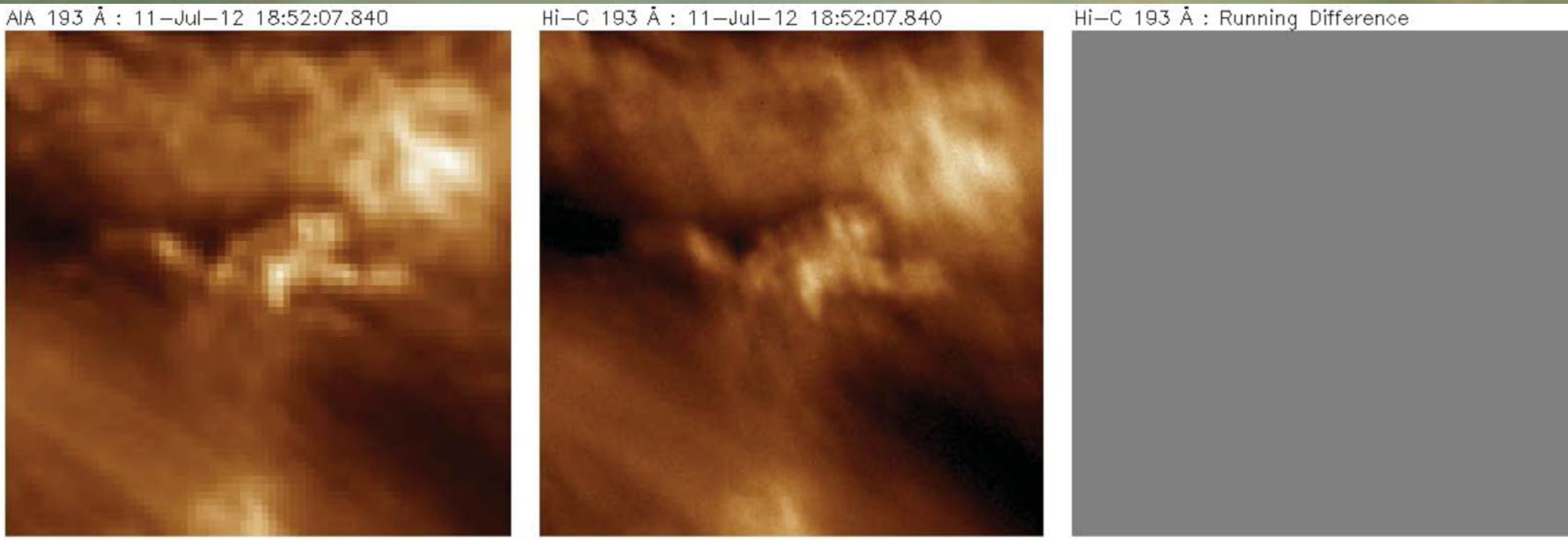
Where is the transition region of active region cores



Warren et al., 2008, ApJ, 677, 1395

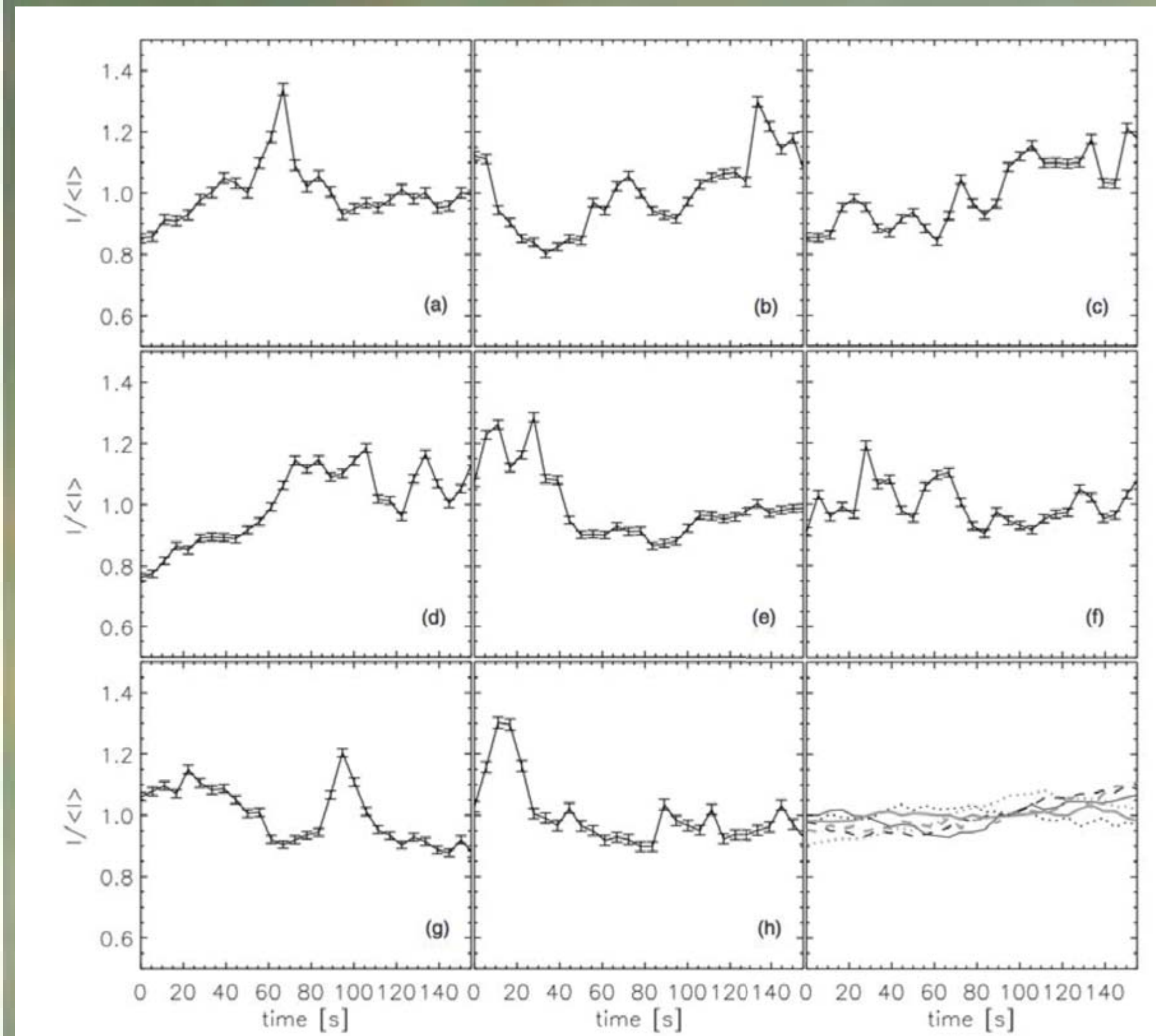
The transition region emission in the moss is too low. This Si VII line is 4 times less intense than predicted. A constriction of the flux tube or absorption by spicules may account for it.

Following the energy in active region cores



Testa et al., 2013, ApJ, 770, 1

Following the energy in active region cores



- Hi-C will observe in 174 Å (better for moss).
- IRIS will co-observe in Si IV and Mg II.
- Follow the temporal evolution of the structures.

Testa et al., 2013, ApJ, 770, 1

What are the heating parameters?

Where is the energy dissipated? **Location**

How long does the energy dissipation last? **Duration**

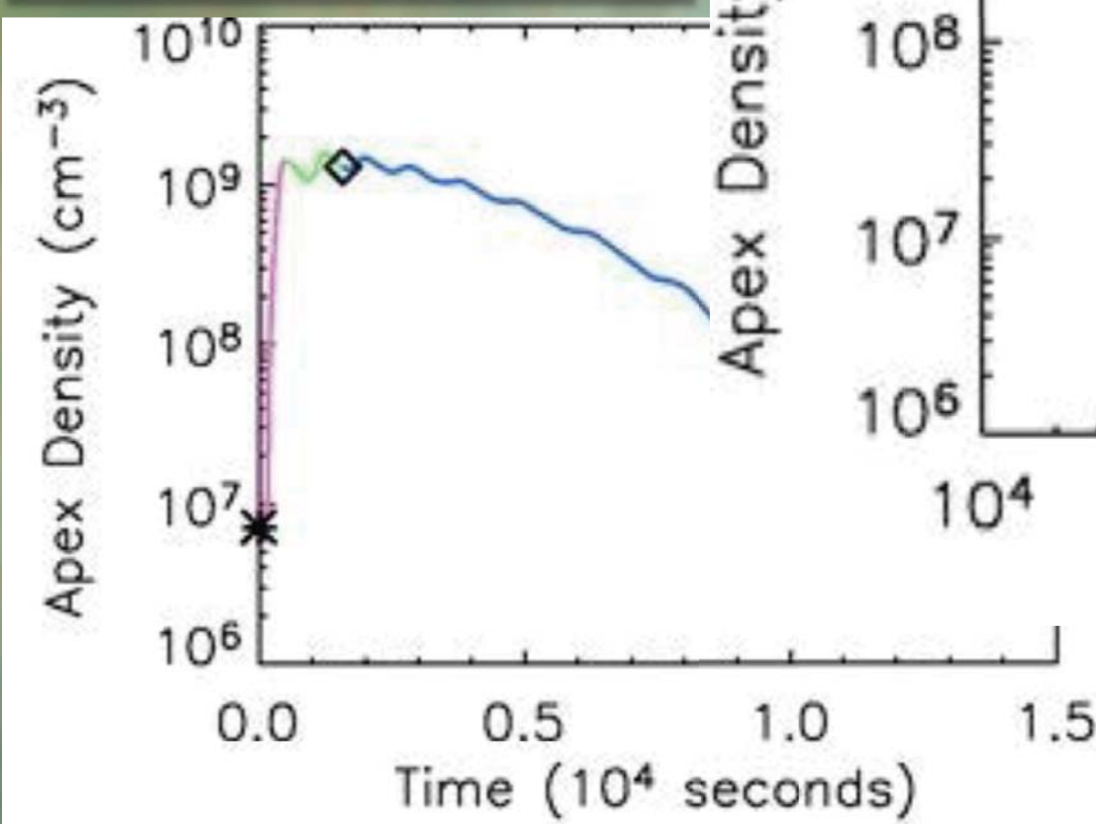
How often does the heating occur? **Frequency**

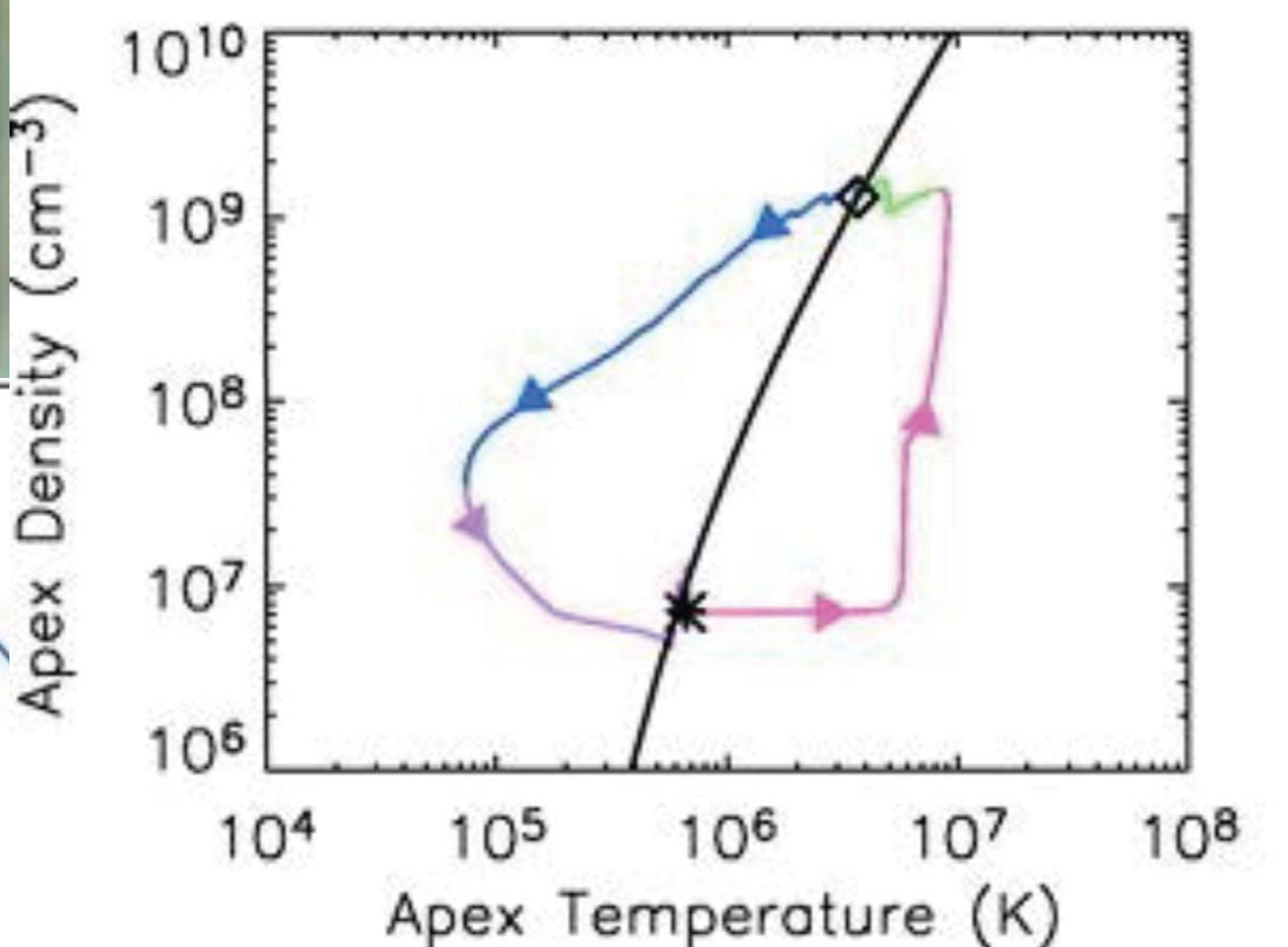
High temperature observations can provide information to determine these parameters.

MaGIXS

Example Impulsive Heating Event

Heating
Conduction
Radiation
Background heating





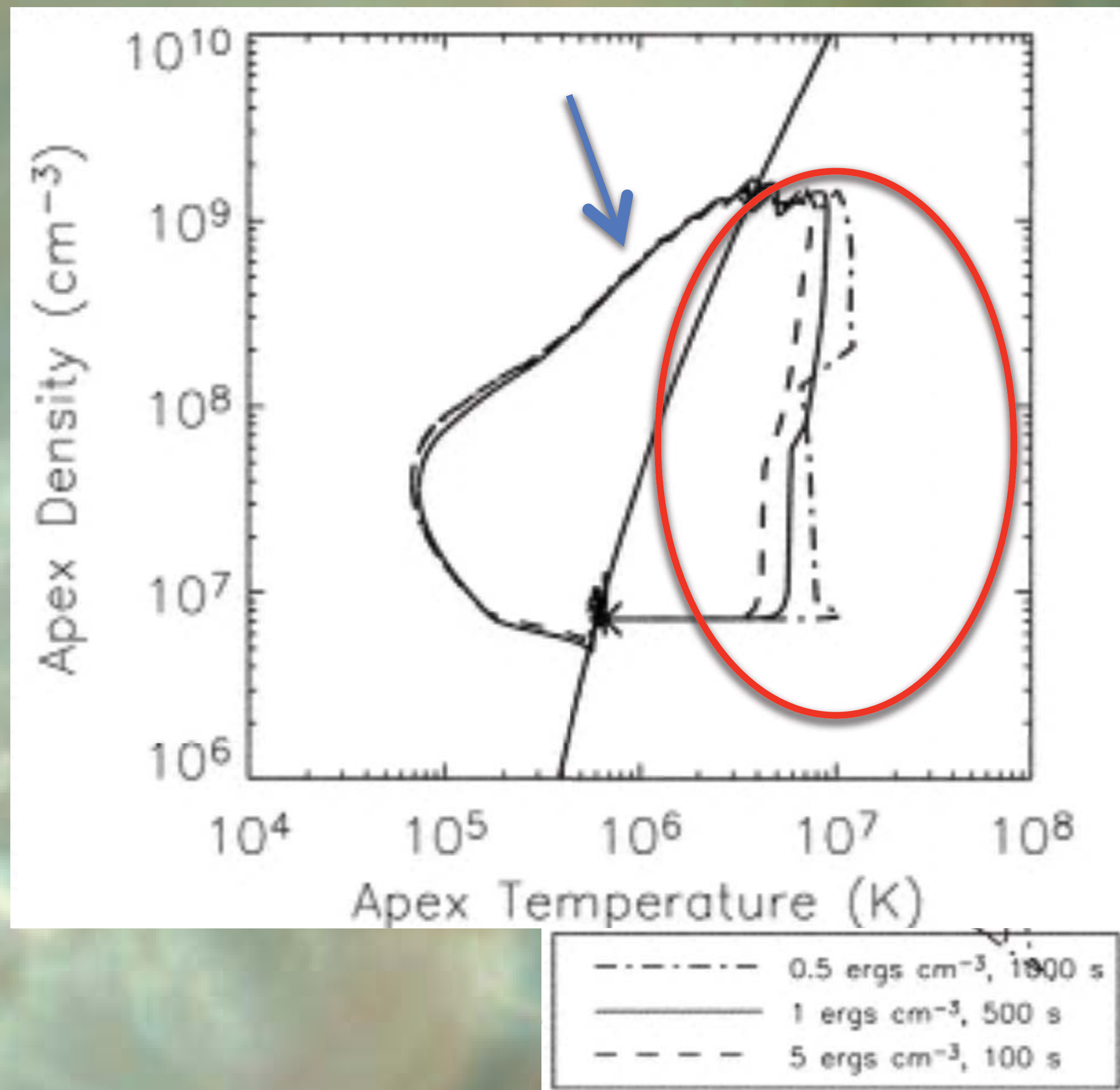
Winebarger et al. 2004, ApJ, 610:L129

Discriminating location and duration

In these simulations, we input the same total energy, but with different durations.

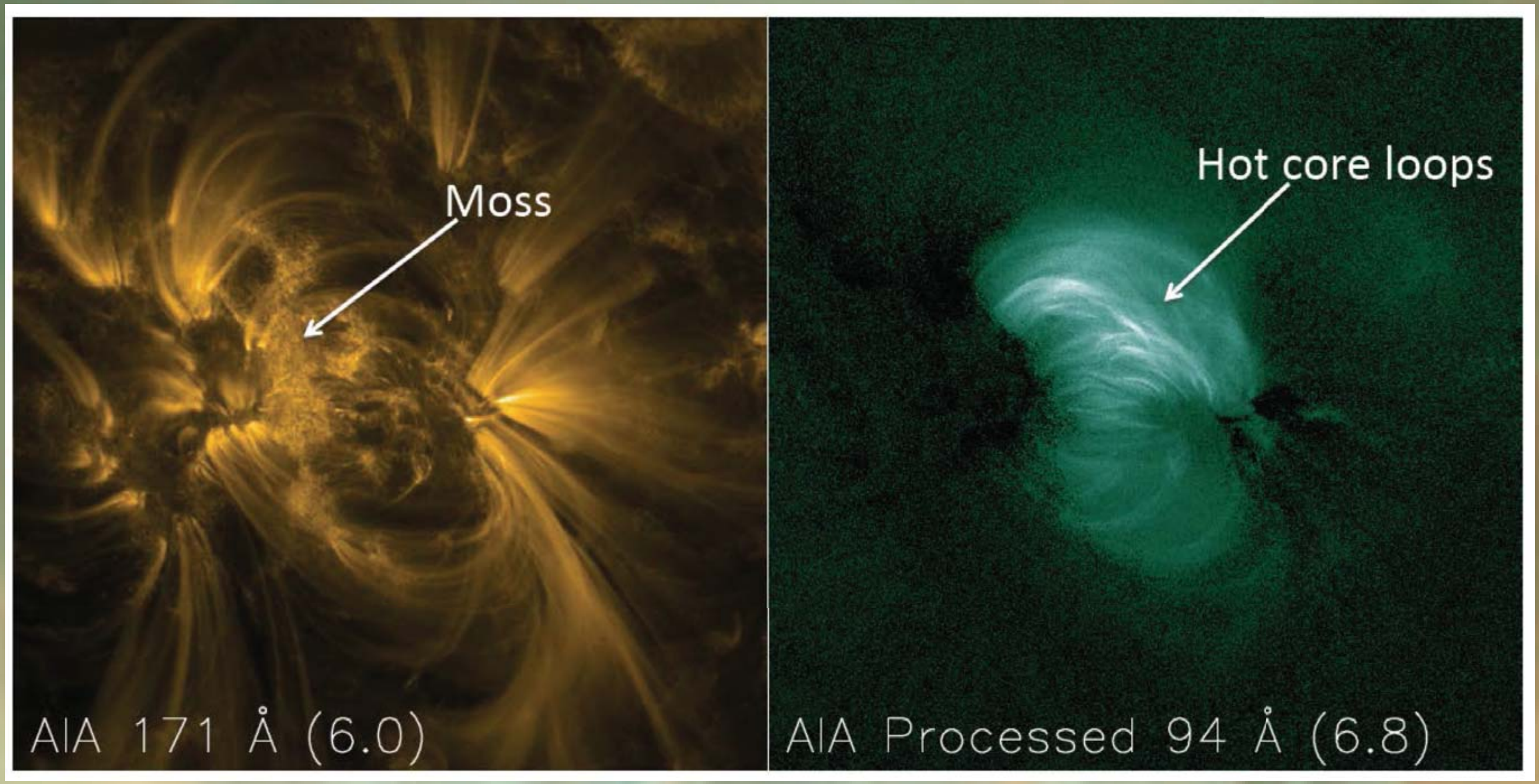
High temperature, low-emission measure observation provide information on location and duration of heating.

Most observations are taken while loops are cooling.



Winebarger et al. 2004, ApJ, 610:L129

Discriminating Frequency

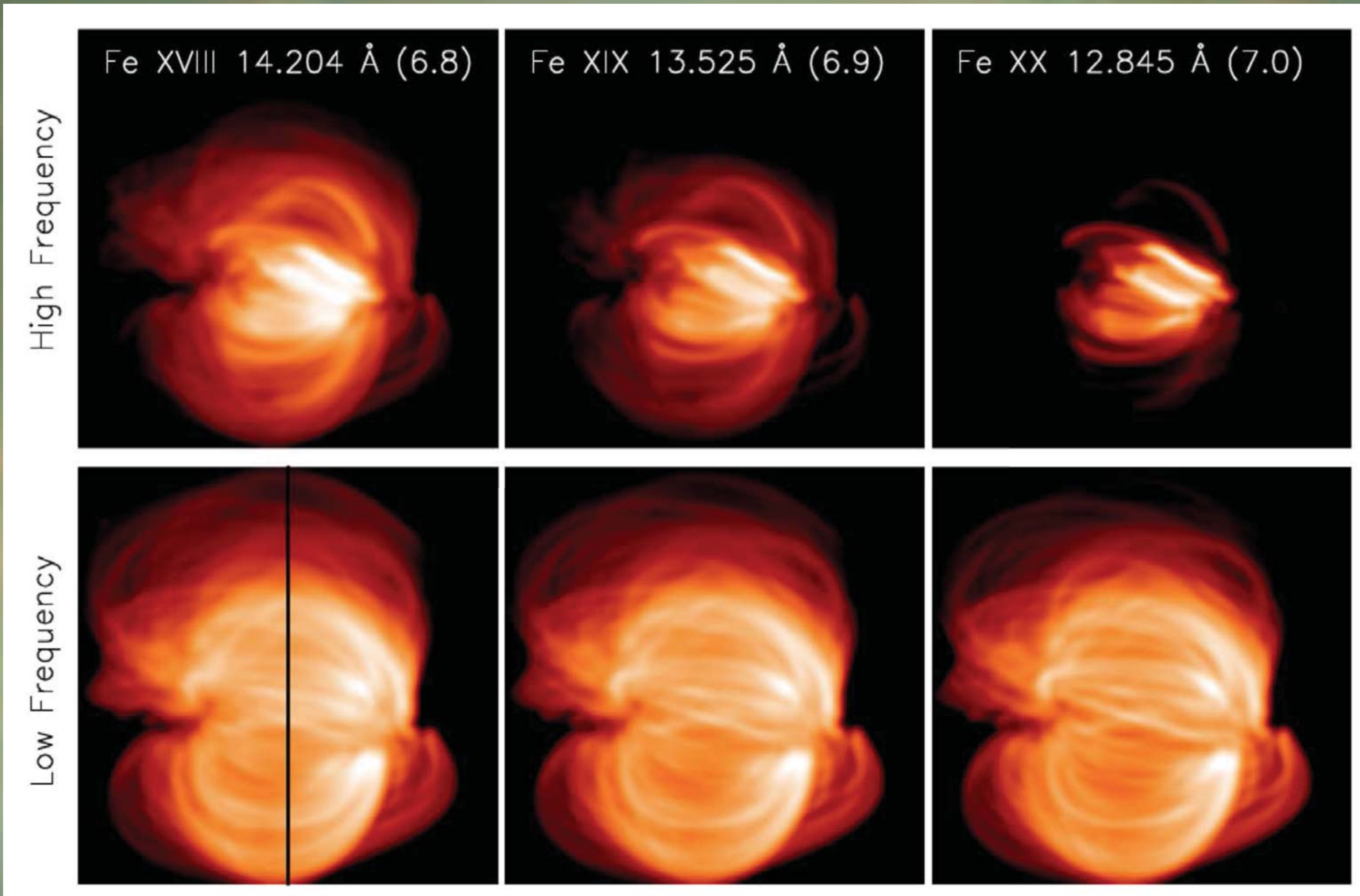


In active region cores, the intensity in the structures is roughly steady.

High-frequency heating = less hot plasma

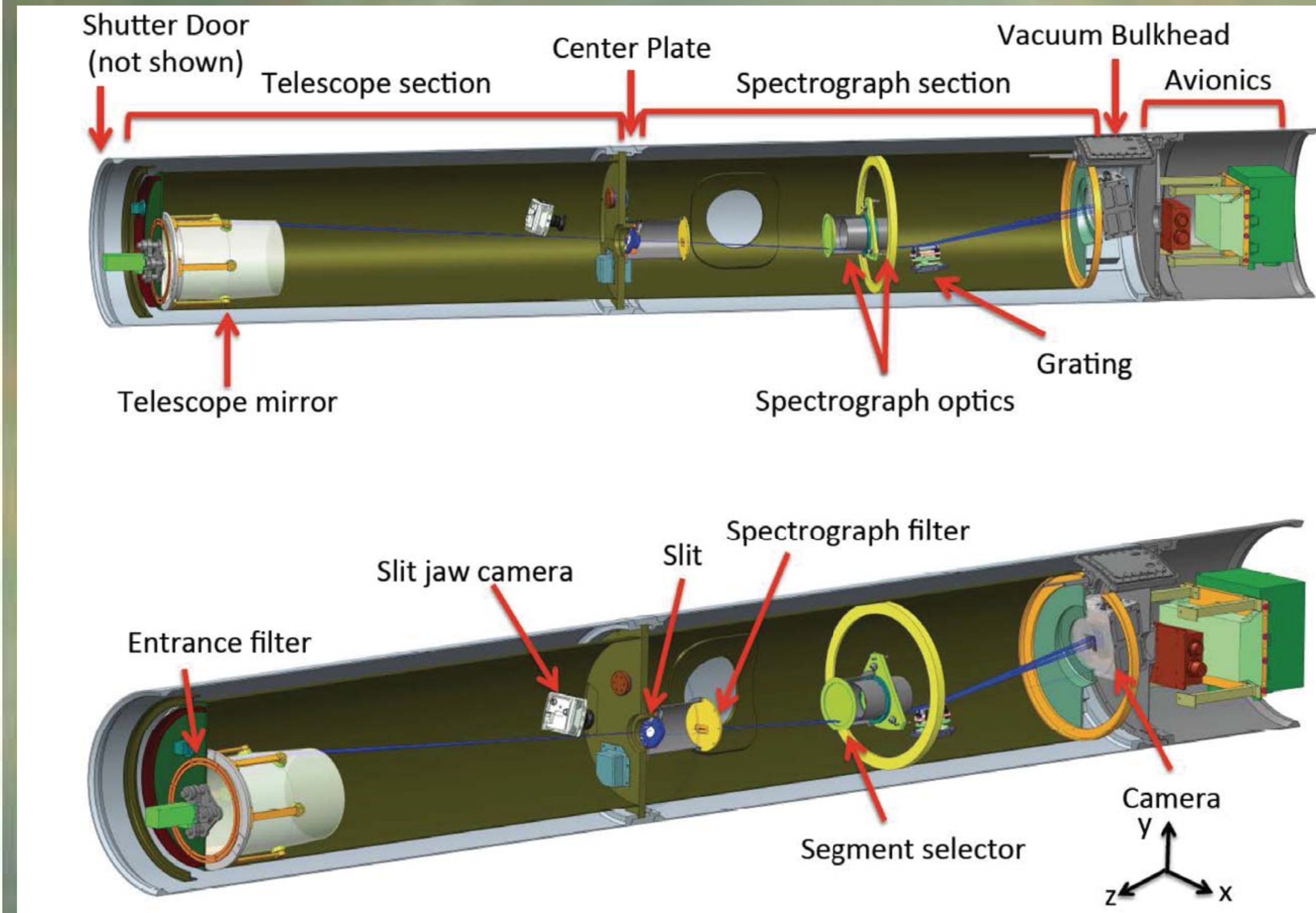
Low-frequency heating = hot plasma

Discriminating Frequency



Warren et al. in prep

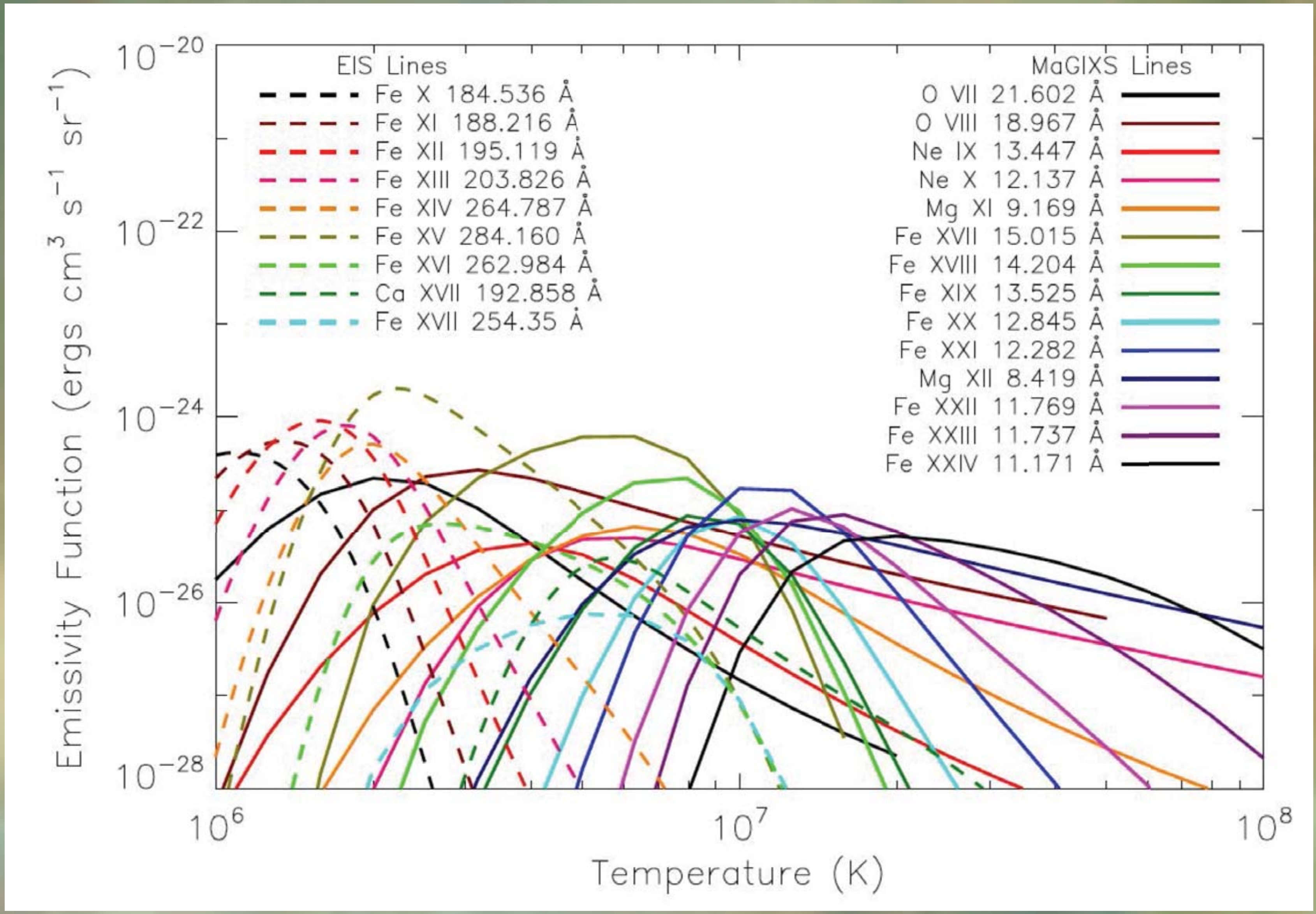
Marshall Grazing Incidence X-ray Spectrometer (MaGIXS)



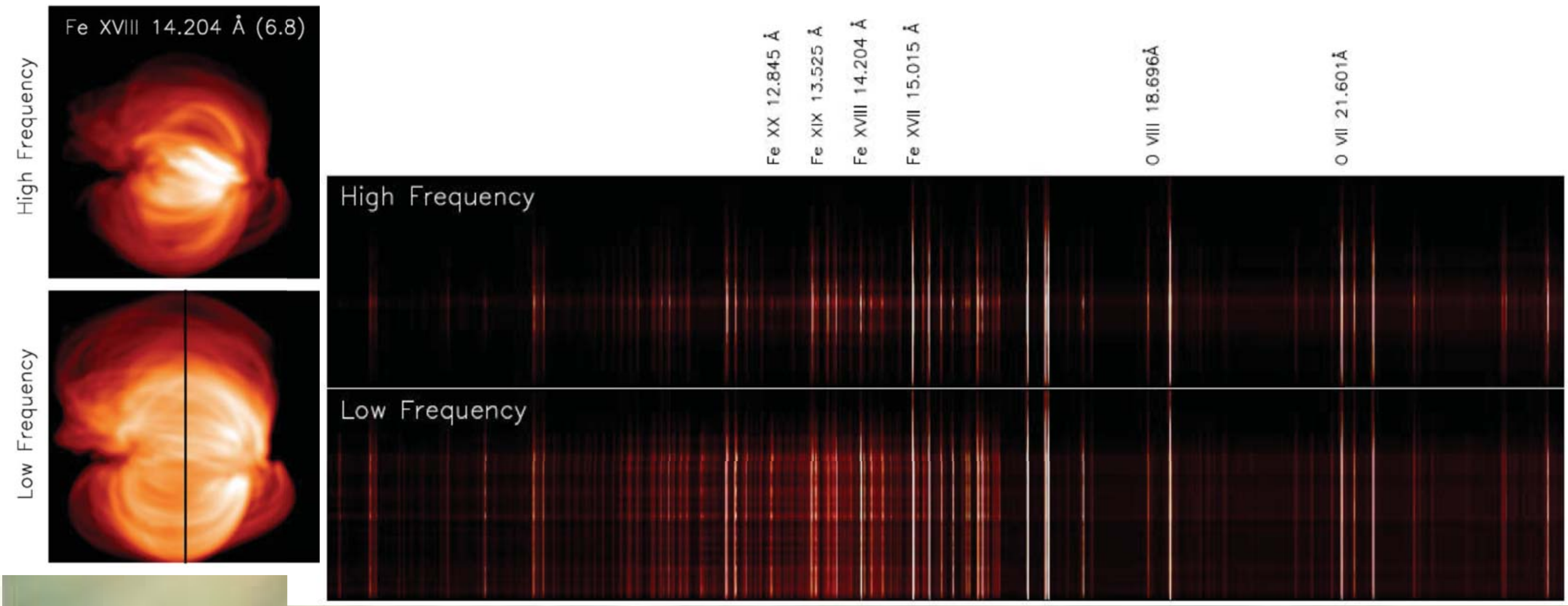
MaGIXS uses a novel design of corrective optics to obtain both spatial and spectral resolution.

Observe:
6-24 Å

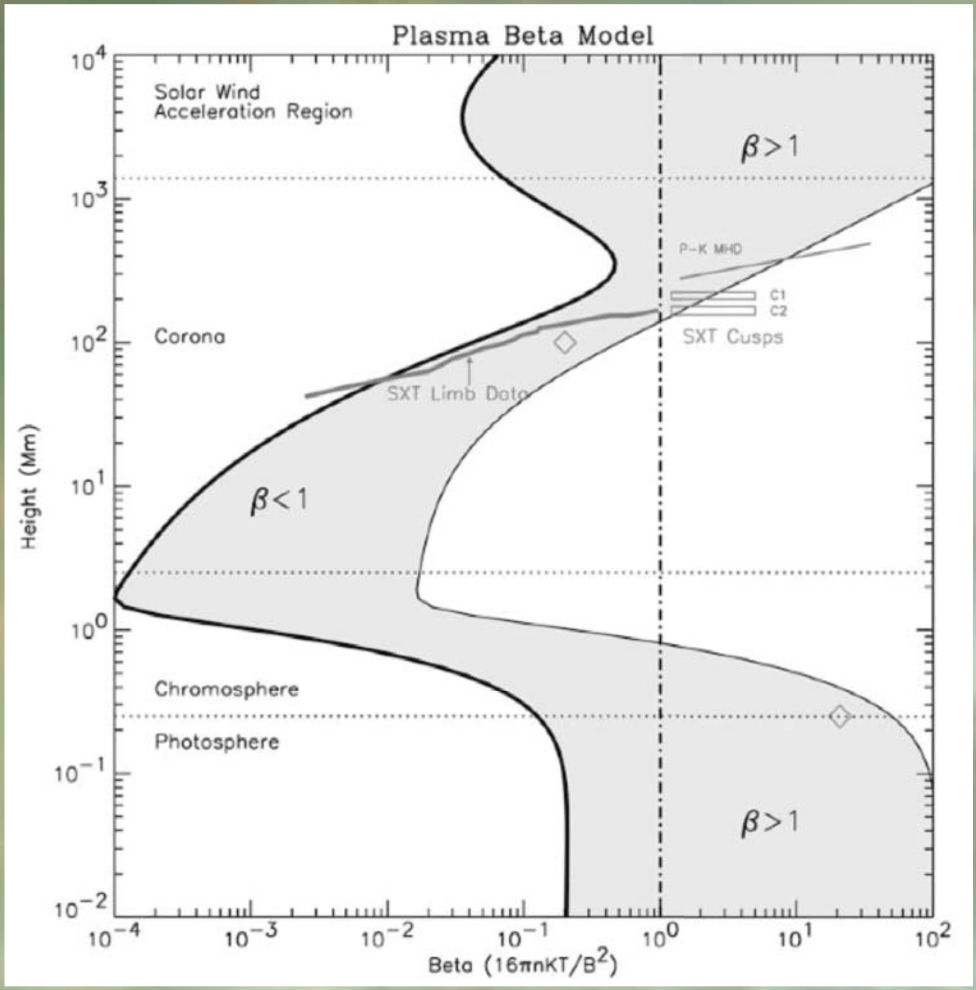
Marshall Grazing Incidence X-ray Spectrometer (MaGIXS)



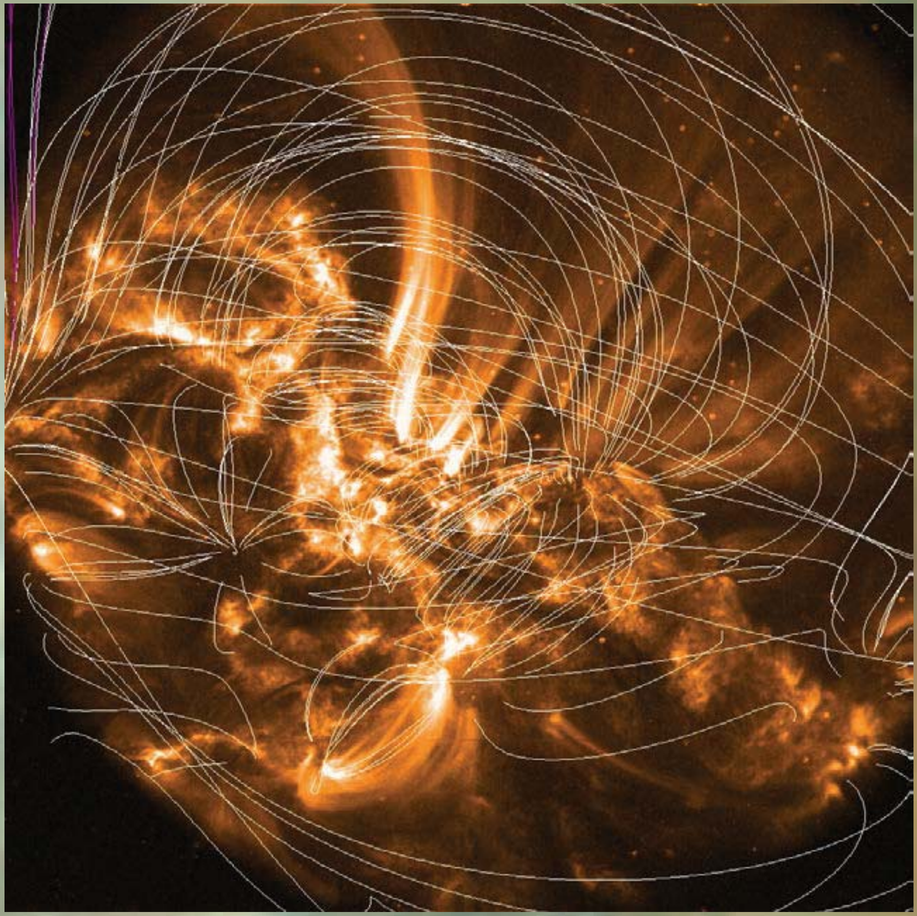
Marshall Grazing Incidence X-ray Spectrometer (MaGIXS)



Potential Field from Photosphere Inadequate

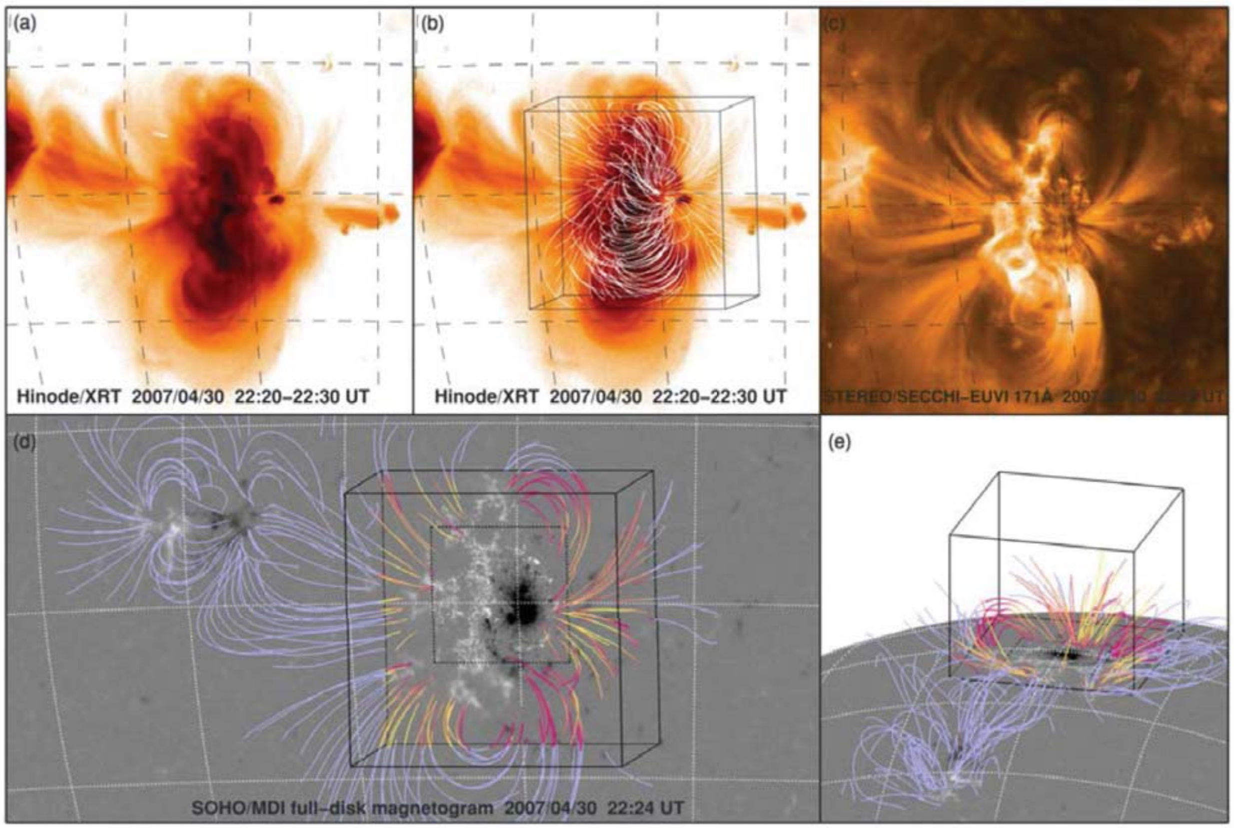


Gary, 2001, Sol Phys, 203, 71

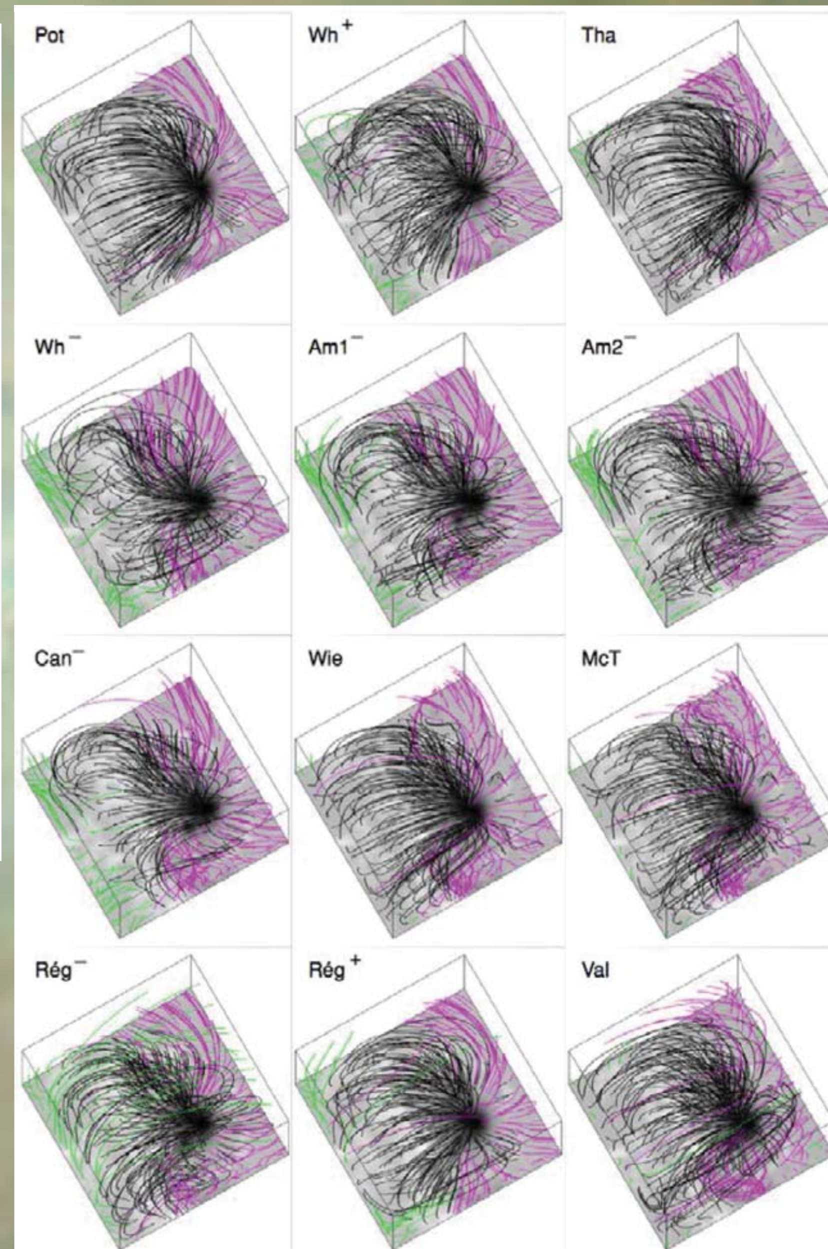


Schrijver et al, 2005, ApJ, 628, 501

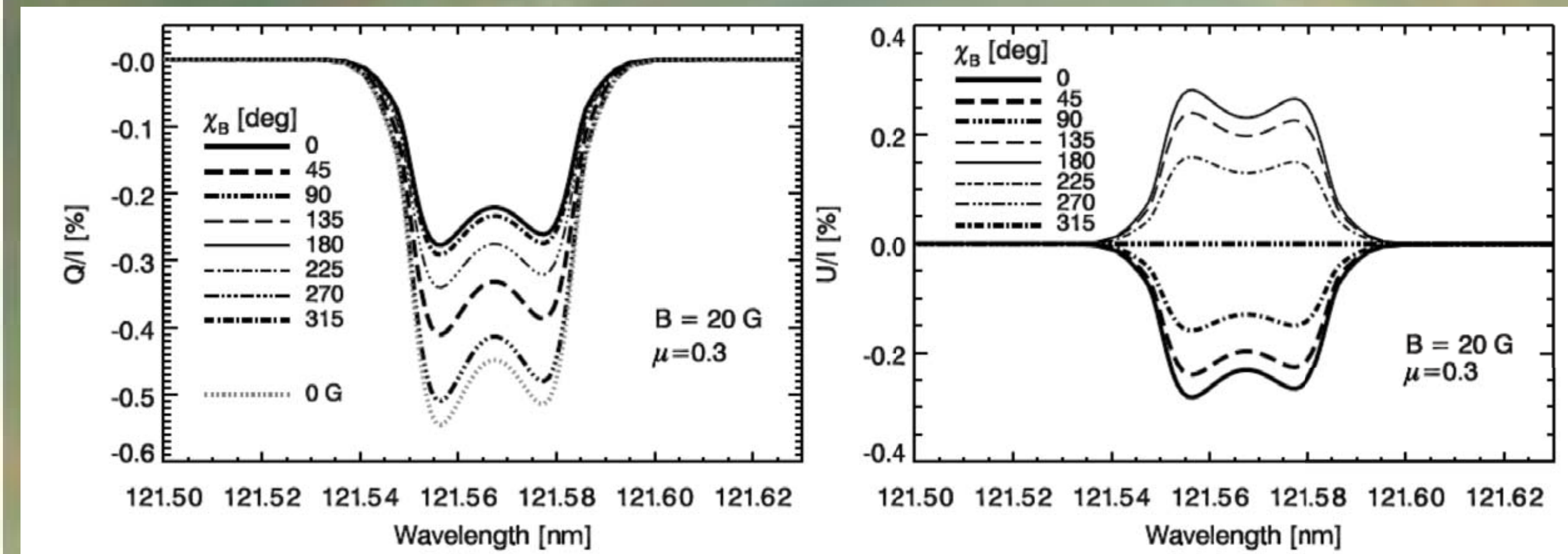
NLFFF Field from Photospheric B Inadequate



De Rosa, 2009, ApJ, 696,1780

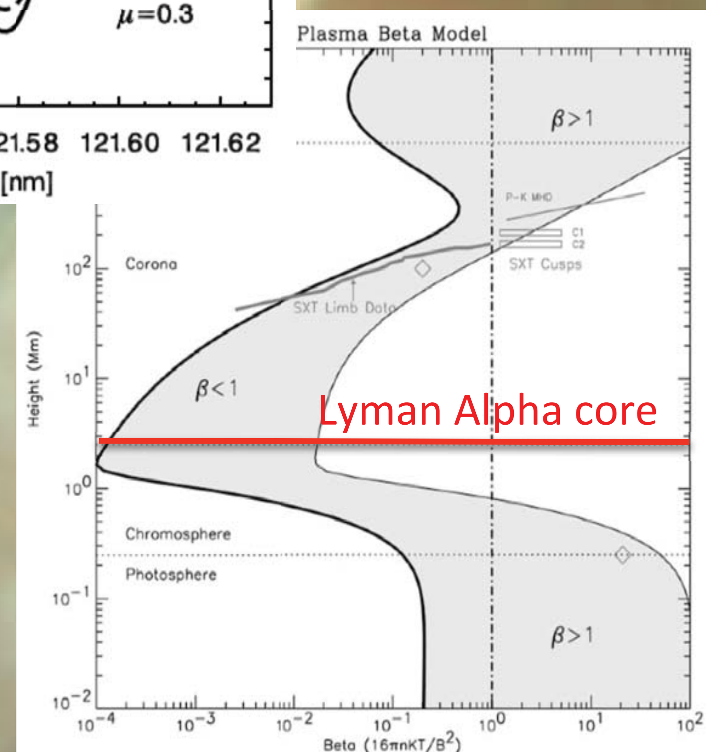


Measuring Chromospheric Magnetic Fields



Trujillo Bueno, 2011, ApJ, 738, L11

Polarization due to Hanle effect of Lyman alpha core is sensitive to magnetic field strength and orientation.



Gary, 2001, Sol Phys, 203, 71

Chromospheric Lyman-Alpha Spectropolarimeter (CLASP)

CLASP will measure the scattering polarization in the wings of Lyman alpha and the polarization due to Hanle effect in the core.

CLASP is due to launch in August 2015 from WSMR.

CLASP is the result of a large international partnership:
USA: MSFC, UAH, LMSAL, HAO, PI: A. Winebarger (MSFC)
Japan: P(NAOJ, JAXA, KU, NIFS) PI: R. Kano (NAOJ)
Spain: PI: J. Trujillo Bueno (IAC)
France: PI: F. Auchère (IAS)
Norway: M. Carlsson (Oslo U.)

MSFC Sounding Rocket Experiments