On the active region cores

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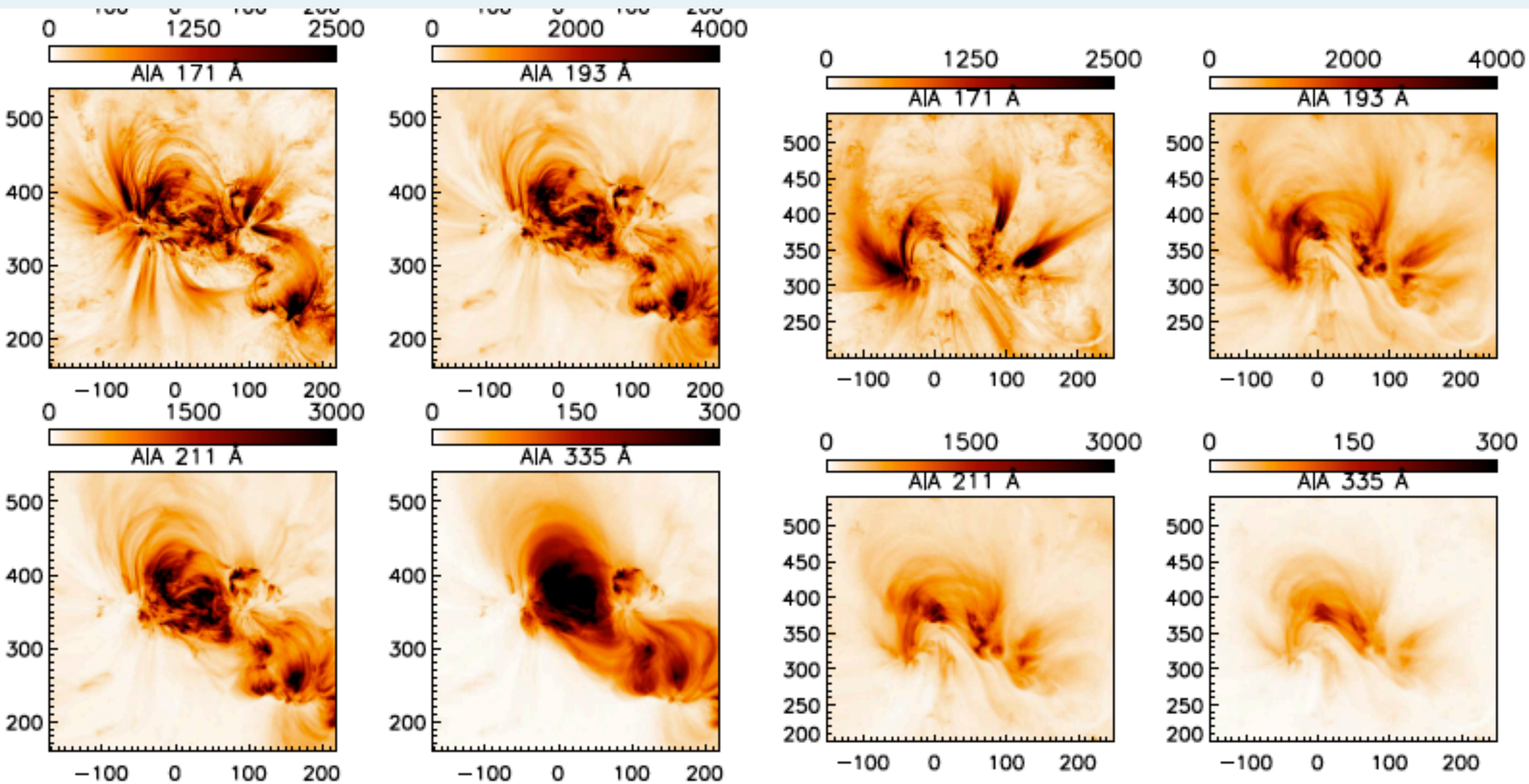
Slope of EM at 1-3 MK from AIA and EIS

Provides in principle a way to distinguish if the heating is high-frequency or low-frequency.

First rotation

Second rotation



Del Zanna et al. (2014)

Slope of EM emission: 1 - 3 MK

$$EM(T) \sim T^b$$

1) Jordan & Wilson (1971) method:

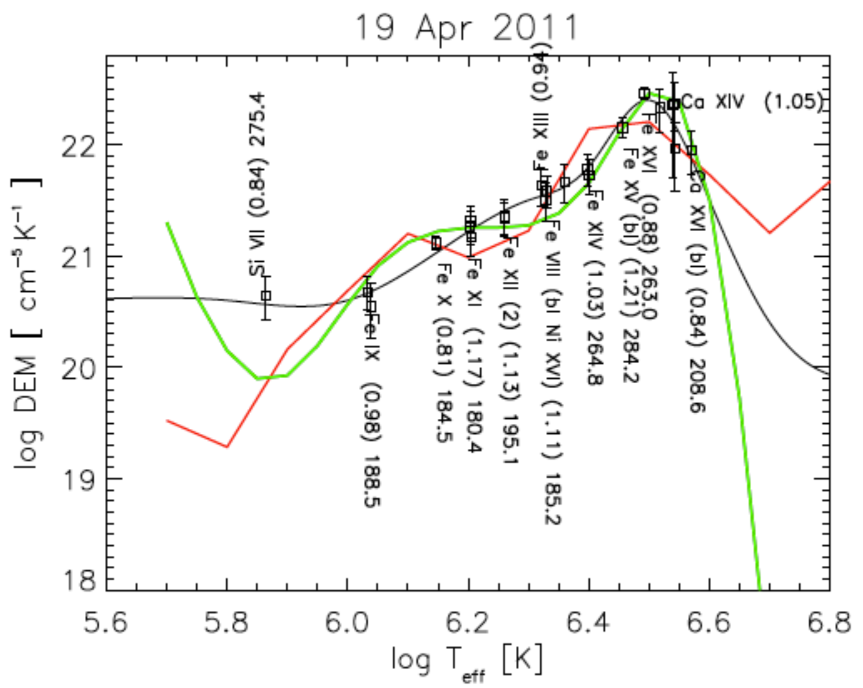
$$EM_{jw} = \frac{I_o}{Ab\, C_\lambda}$$

$$C_\lambda = \frac{\int G_\lambda(T)dT}{T_{mem}(10^{0.15} - 10^{-0.15})}.$$

Estimate of the slope in the 1-3 MK range is obtained from the EMjw of Fe IX and Fe XVI.

Similar slopes are obtained from AIA.

2) EM from the DEM



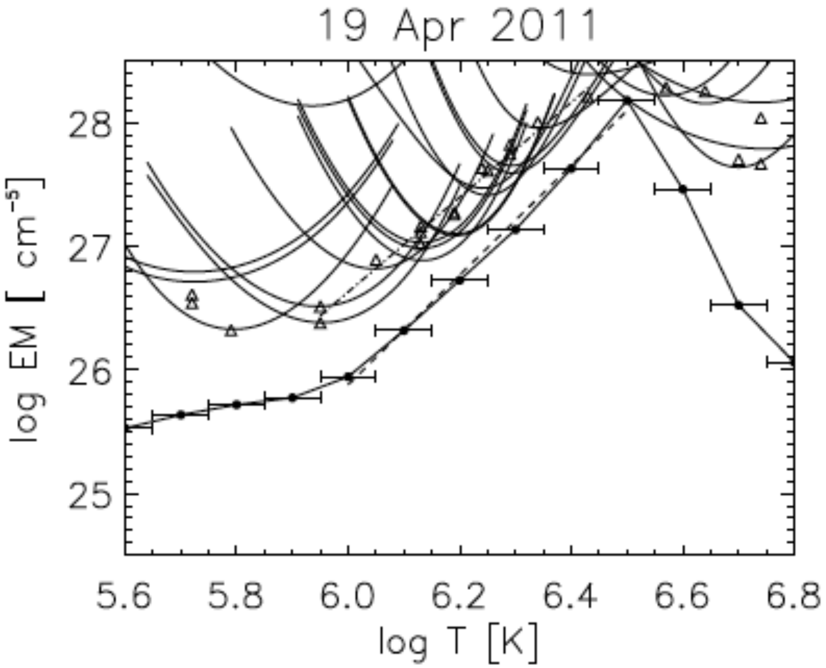
Red: MCMC

Green: XRT_DEM

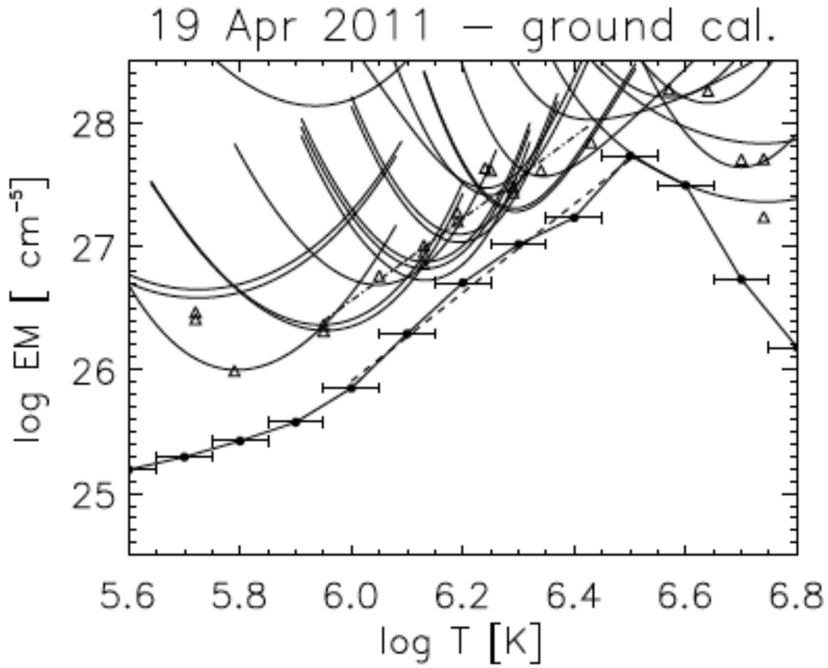
Black: Del Zanna (spline)

Slope of emission – first rotation

Hinode EIS
Ground-based calibration

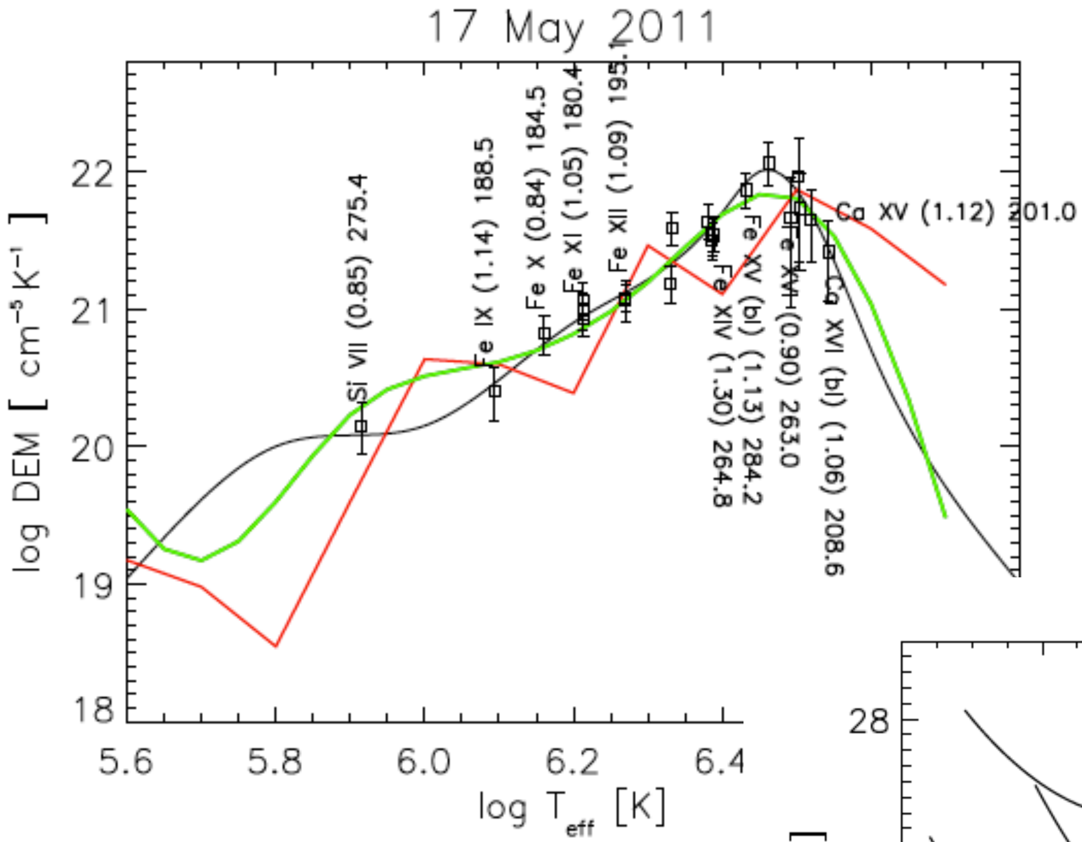


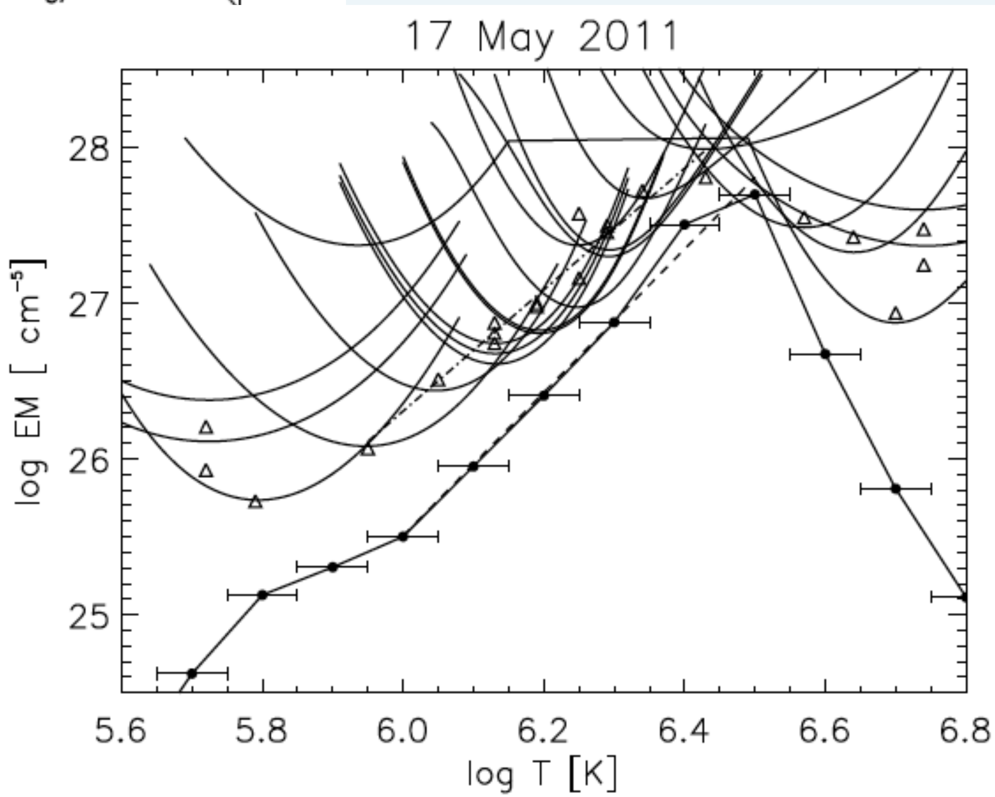
Hinode EIS
Del Zanna (2013) calibration



Slope: 4.4
(3.8 with EMjw)

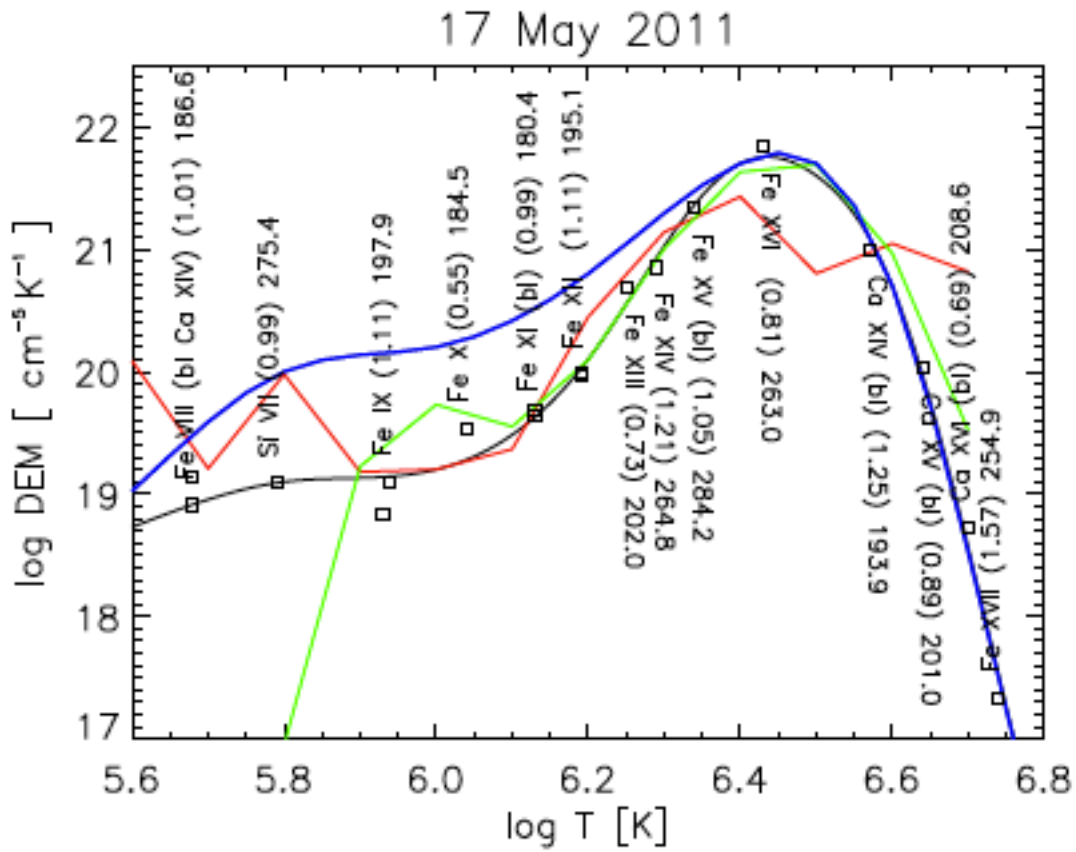
Slope: 3.6
(3.3 with EMjw)



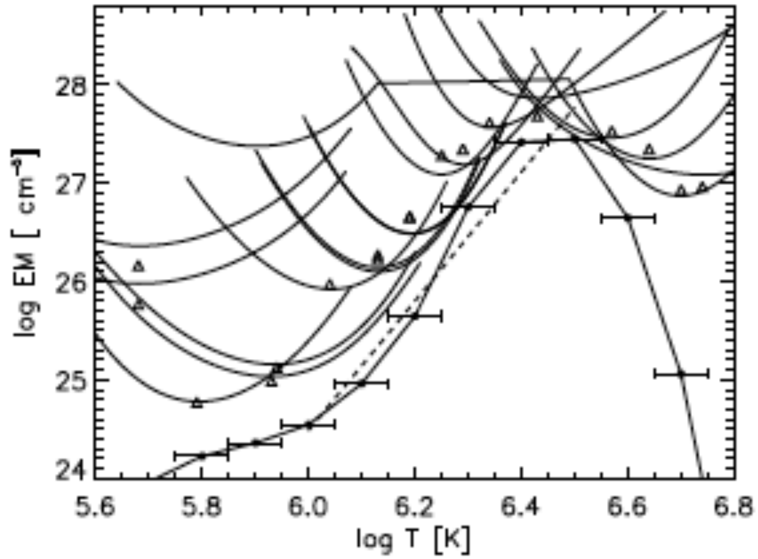


Slope=4.6
(3.9 with EMjw)

Slope of emission – background subtraction

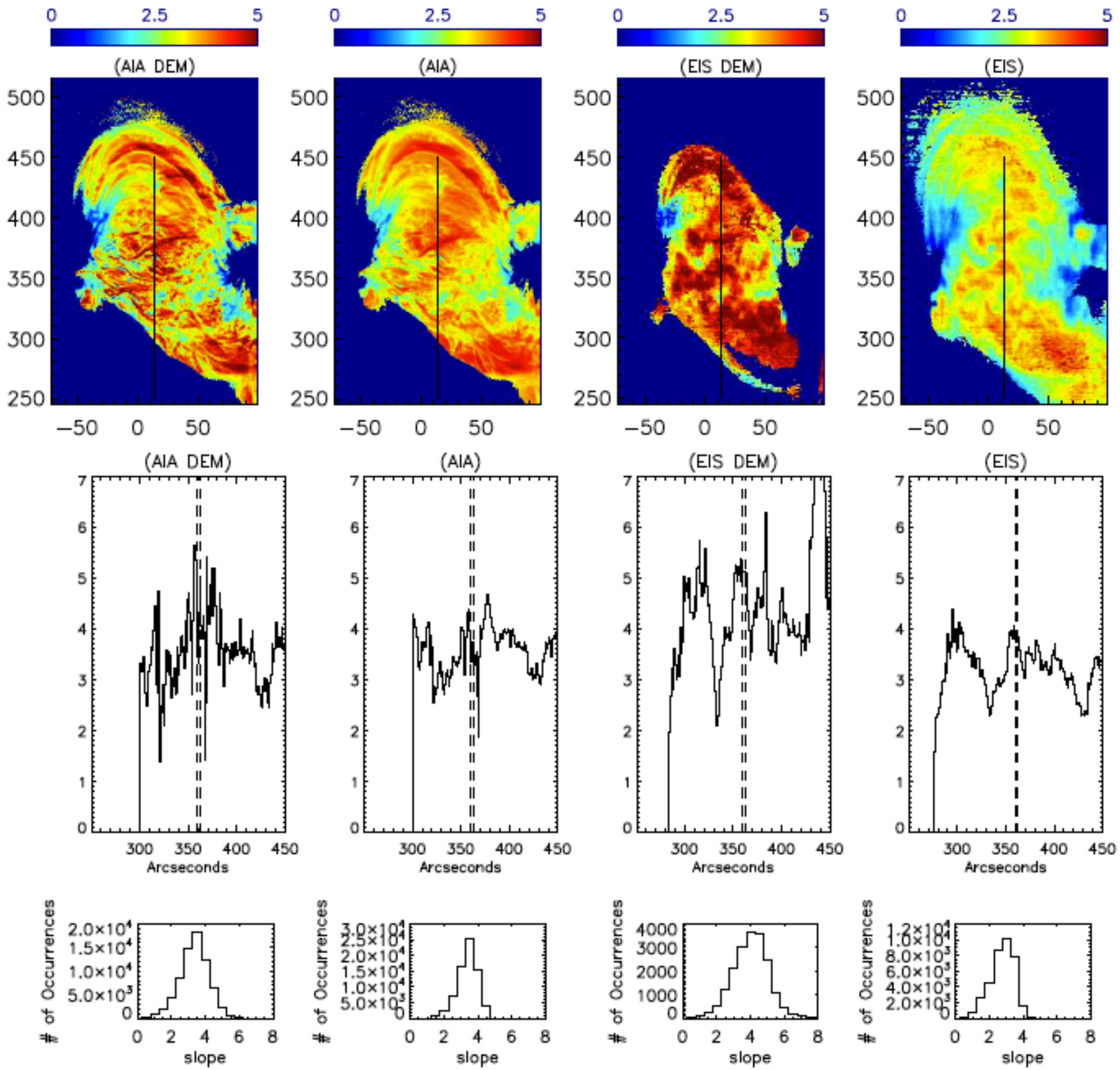


Background-subtracted,
Del Zanna (2013) calibration

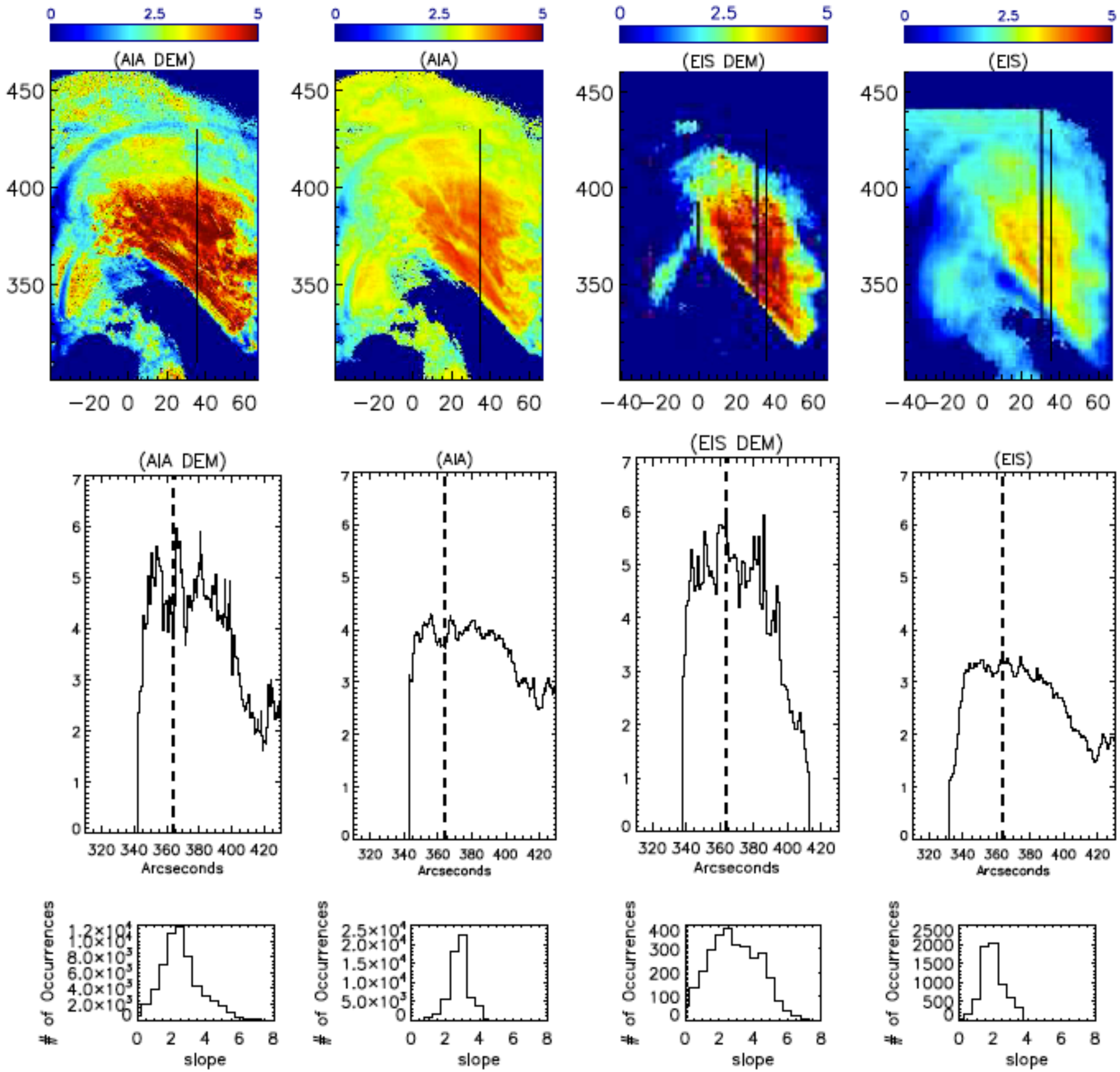


Red: MCMC
Green: XRT_DEM
Black: Del Zanna (spline)
Blue: not background-subtracted

Slope=6.6
(5.1 with EMjw)



First
rotation



Second rotation

Del Zanna abundances for AR core loops

Hinode EIS measurements of 3 MK emission allows measurements of the FIP bias (see poster from Vitti et al.)
1) FIP bias of π.
2) Fe must be enhanced by at least a factor of 3
3) FIP bias is about 2 in AR 1-3 MK plasma (Del Zanna 2013)

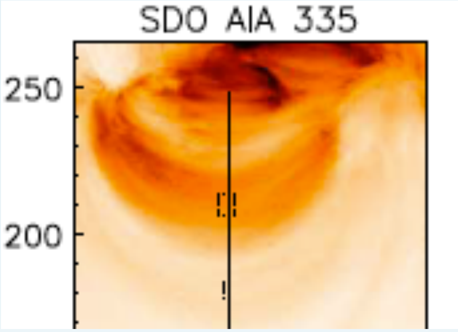


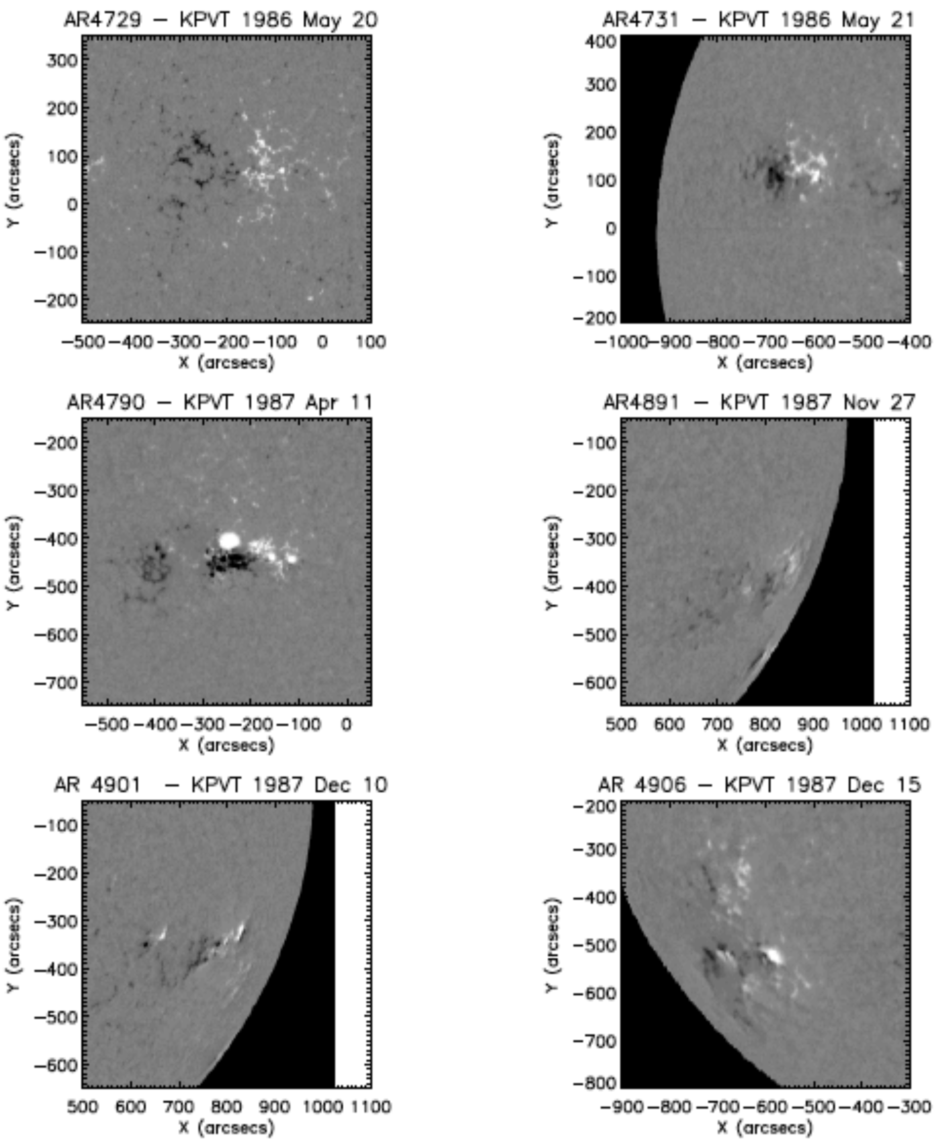
Table 1. Abundance measurements relative to iron (Del Zanna 2013; Del Zanna & Mason 2014)

El.	FIP (eV)	AR core	"Photospheric"	Ratio	
Fe/Ne	7.9/21.5	1.2	0.34 (G), 0.37 (QS), 0.8 (SW)	3.5 (G), 3.2 (QS), 1.5 (SW)	X-ray
Fe/Ar	7.9/15.8	50	7.4 (G) - 33 (SW)	6.8 (G), 1.5 (SW)	EUV
Fe/O	7.9/13.6	0.2	0.065 (A)	3.1	X-ray
Fe/S	7.9/10.4	6.8	2.4 (A)	2.8	EUV
Fe/Si	7.9/8.1	1.0	1.0 (A)	1.0	EUV
Fe/Ni	7.9/7.6	29.5	19.1 (A)	1.5	EUV
Fe/Ca	7.9/6.1	13.5	14.5 (A)	0.93	EUV

Notes. QS: quiet - Sun EUV measurements of neon (Del Zanna, in prep.). SW: fast solar wind observations from Gloecker and Geiss (2007). G: Galactic, for neon, Morel and Butler (2008) from Ne I and Ne II lines in nearby, early B-type stars argon: Lanz et al. (2008), from B main-sequence stars in the Orion association ; A: (Asplund+2009)

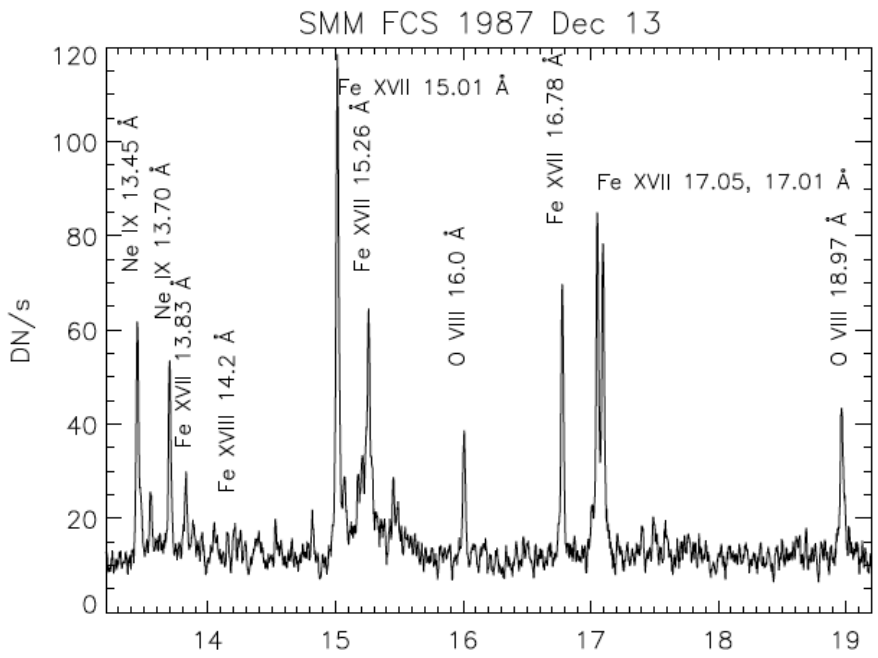
SMM FCS and BCS

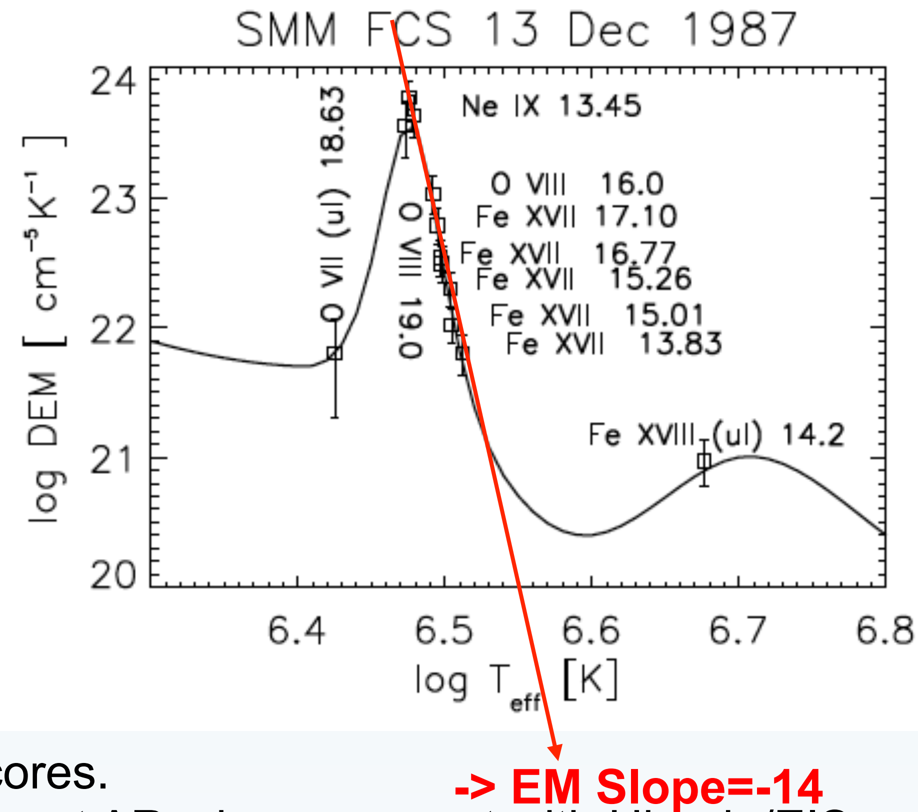
Re-analysed, with recent atomic data, X-ray spectra of quiescent active region cores from SMM FCS (Del Zanna & Mason 2014, A&A).



Date	NOAA	Times (UT)	BCS	Neon	FIP
1986 Feb 14	4713		variable		
1986 May 20	4729	00:33, 00:43, 00:53	quiet	High	3.2
1986 May 18	4731		variable		
1986 May 21	4731	14:16, 14:26, 14:35	quiet	Low	5?
1986 May 23	4731		quiet		
1986 May 24	4731	05:03,05:13,05:22,05:32	quiet	Low	3.2
1986 Jul 13	4736		no		
1986 Jul 14	4736		variable		
1987 Apr 9	4790		variable		
1987 Apr 11	4790	22:32, 22:41, 22:51	quiet	Std.	3.2
1987 Apr 13	4790	01:14,01:24,01:33,01:43	quiet	Std.	3.2
1987 Apr 14	4790	14:56,15:06,15:15	quiet	Std.	3.2
1987 Apr 15	4790		variable		
1987 Apr 16	4790		no/variable		
1987 Apr 17	4790		variable		
1987 Apr 18	4790		variable		
1987 Apr 19	4790		variable		
1987 May 22	4811		variable		
1987 May 26	4811		variable		
1987 May 29	4811		variable		
1987 Nov 27	4891	16:25,16:35,16:45,16:54	quiet	Low	5
1987 Nov 29	4891		variable		
1987 Dec 6	4901		variable		
1987 Dec 7	4901		no		
1987 Dec 8	4901		no		
1987 Dec 9	4901		no		
1987 Dec 10	4901		no		
1987 Dec 11	4901	2:18,2:28,2:38,2:48,2:58	quiet	?	3.2
1987 Dec 11	4901	(10:04–11:04)†	variable		
1987 Dec 13	4906	09:16, 09:26, 09:36,09:46	quiet	Std.	3.2
1987 Dec 15	4906		variable		
1987 Dec 16	4906		variable		
1987 Dec 18	4906		variable		
1987 Dec 20	4906		no		

X-ray spectroscopy from SMM FCS





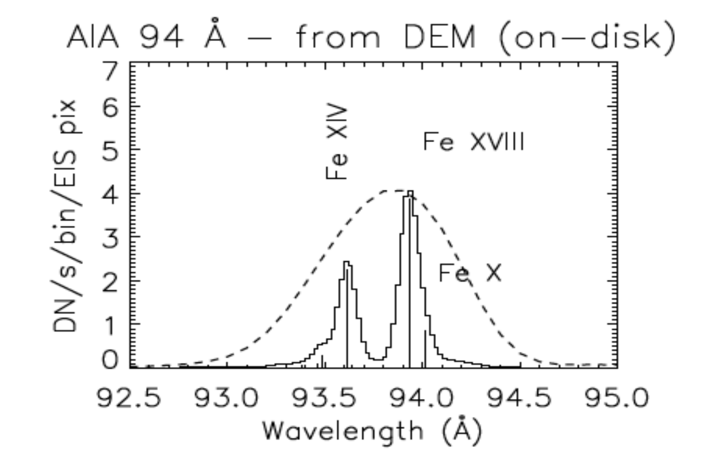
1) Almost no emission above 3 MK in the cores.
2) Increased FIP=π (Fe/O and Fe/Ne) for most ARs, in agreement with Hinode/EIS results (Del Zanna 2013, A&A), but disagreement with previous literature.

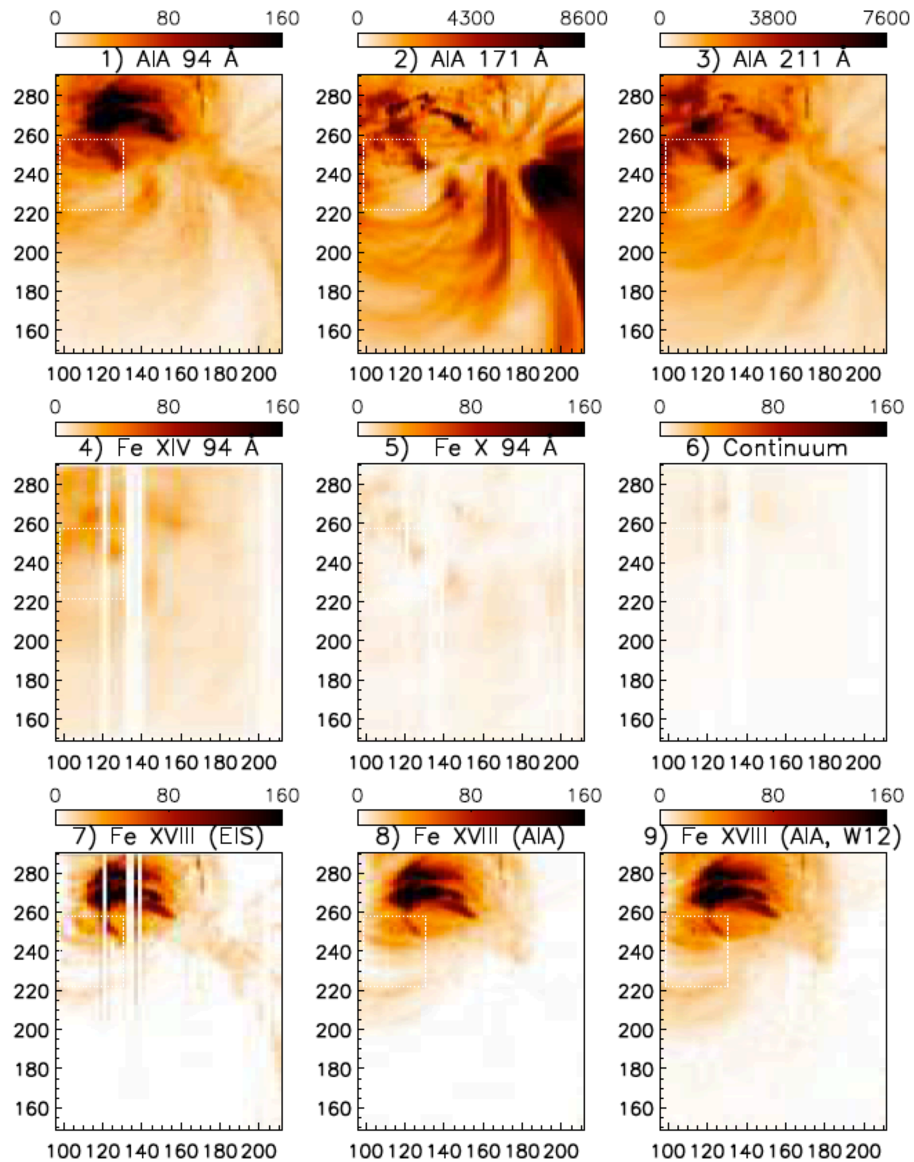
Fe XVII is formed at 3 MK. How much plasma is there above 3 MK is constrained by Fe XVIII and higher stages.

MAGIXS will observe the same spectral region with spatial resolution

Fe XVIII and AIA 94 A

AIA 94 images show ubiquitous presence of Fe XVIII



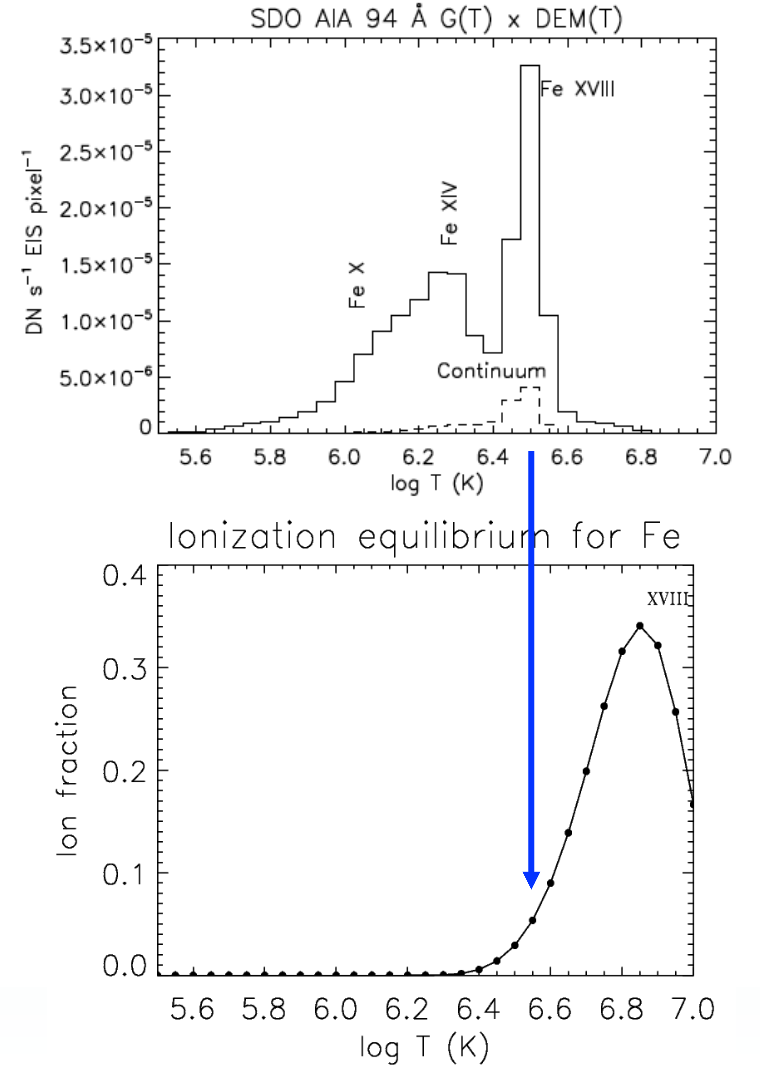


New Fe XIV identification (Del Zanna 2012): strong contribution to AIA 94 A

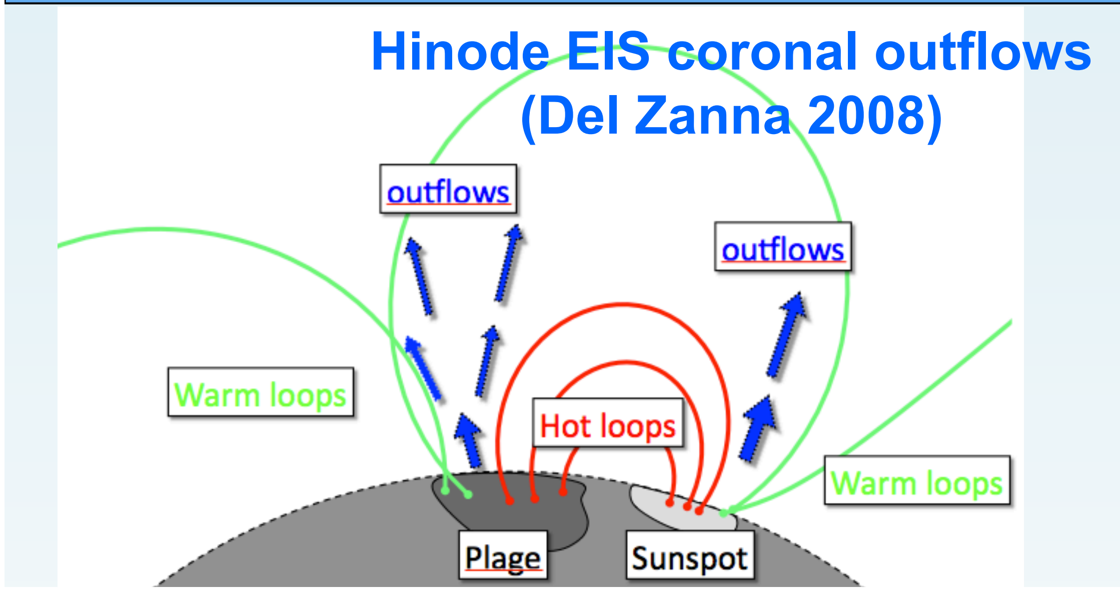
It is possible to estimate the Fe XVIII contribution (Del Zanna 2013)

Fe XVIII and AIA 94 A

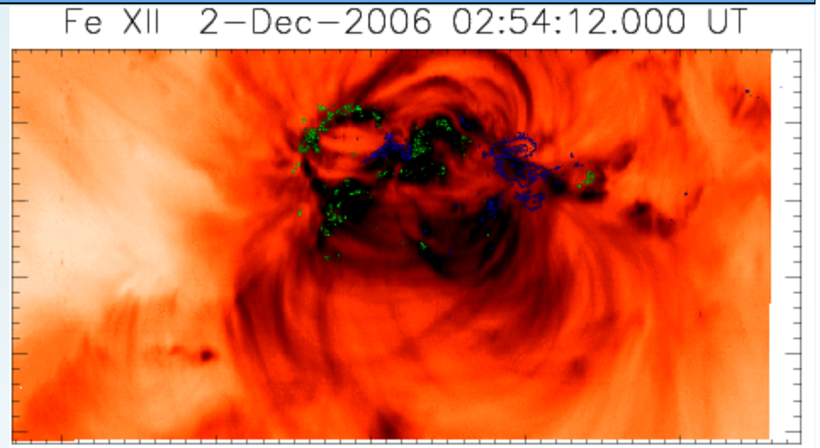
Some Fe XVIII is often present, but in many regions it is formed at 3 MK and not 7 MK! (Del Zanna 2013)

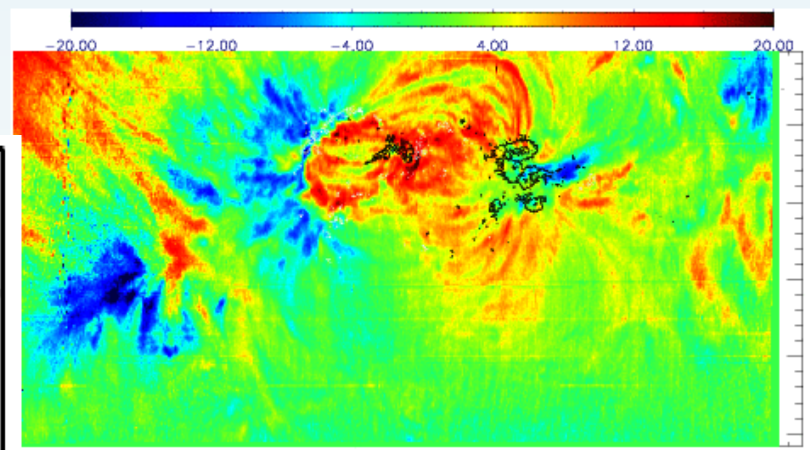


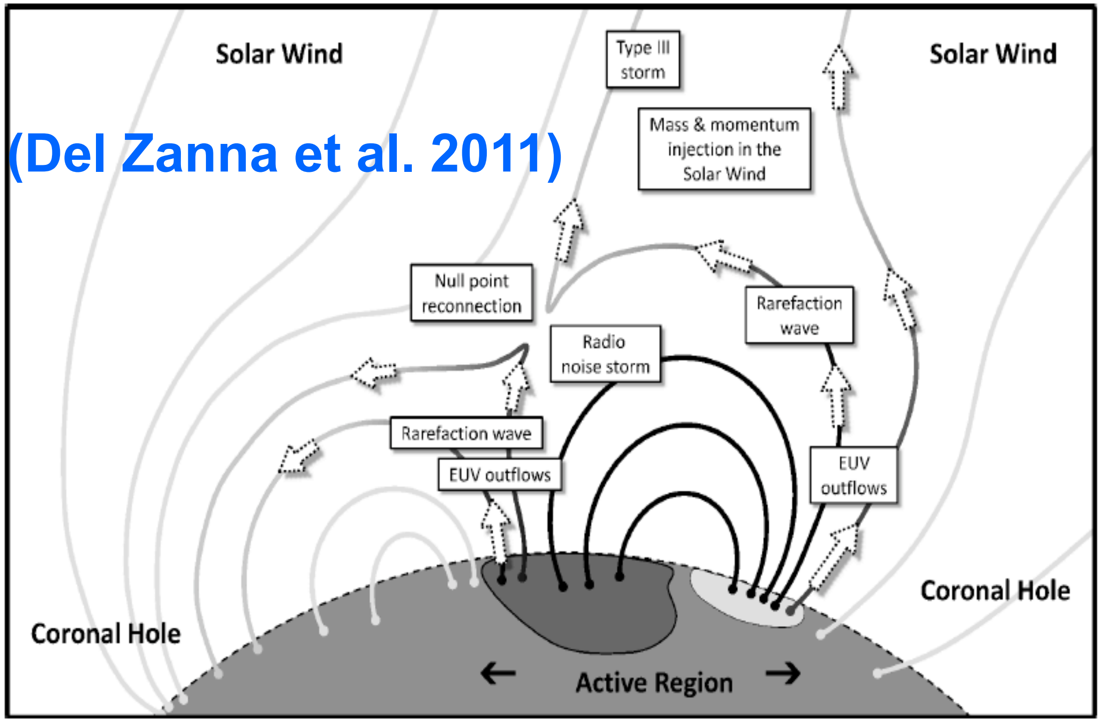
Hot loops produce some warm loops?



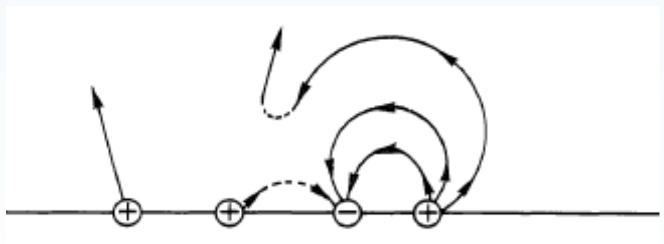
Hinode EIS coronal outflows
(Del Zanna 2008)







(Del Zanna et al. 2011)



Sheely et al. (1975) from
Skylab observations

Conclusions and future

EUV and X-ray observations of hot core loops in different ARs have similar near-isothermal distributions around 3 MK, and an FIP bias of π

Spatially-resolved X-ray spectroscopy is really needed to study the heating in AR cores.

MAGIXS, the first X-ray spectrometer since 1980's, will provide important constraints above 3 MK. See the poster.