Active region loops: Hinode/EIS observations

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Coronal loops: Open questions

- **Loops are fundamental building blocks of active regions:**
  - Studying coronal loops will help to understand the mechanisms responsible for active region heating and coronal heating in general.

- **Questions of prime importance:**
  - Loop structures appear fuzzier at higher temperatures: is it real or just the matter of spatial resolution?
  - What are the plasma flow structures in the active region loops?
  - What are the values of densities and the filling factors of a coronal loop? How do they vary along the loop length?
  - Are active region loops **iso-thermal or multi-thermal** along the LOS? How does the temperature vary along the loop length?

Coronal loops: EIS observations

- We can measure flows with a precision of ±3 km/s in spatially resolved coronal structures simultaneously at different temperatures from **log T = 5.6 MK (Fe VIII) to log T = 6.4 (Fe XV).**

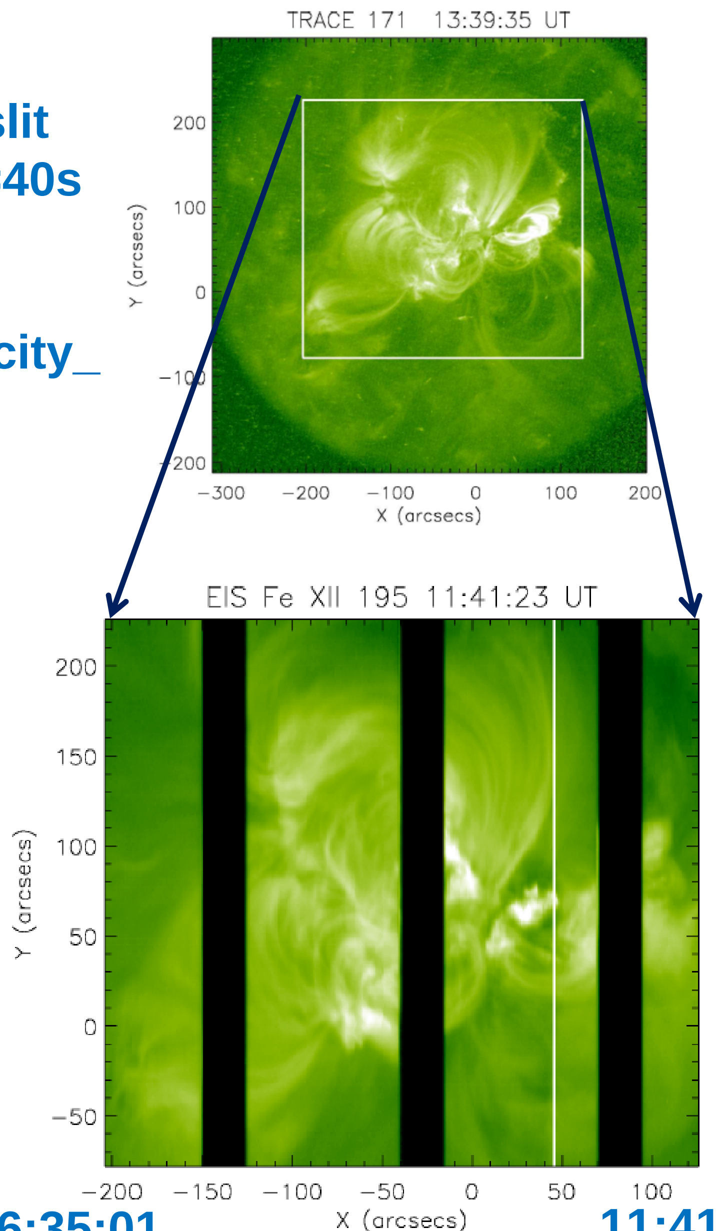
- We can measure electron density more precisely than ever before and therefore, filling factors at different temperatures simultaneously.

- We can study temperatures along the LOS using emission measure analysis.

EIS observations: May 19, 2007

1 arcsec slit
Exp time=40s

Obs seq:
"AR_velocity_maps"



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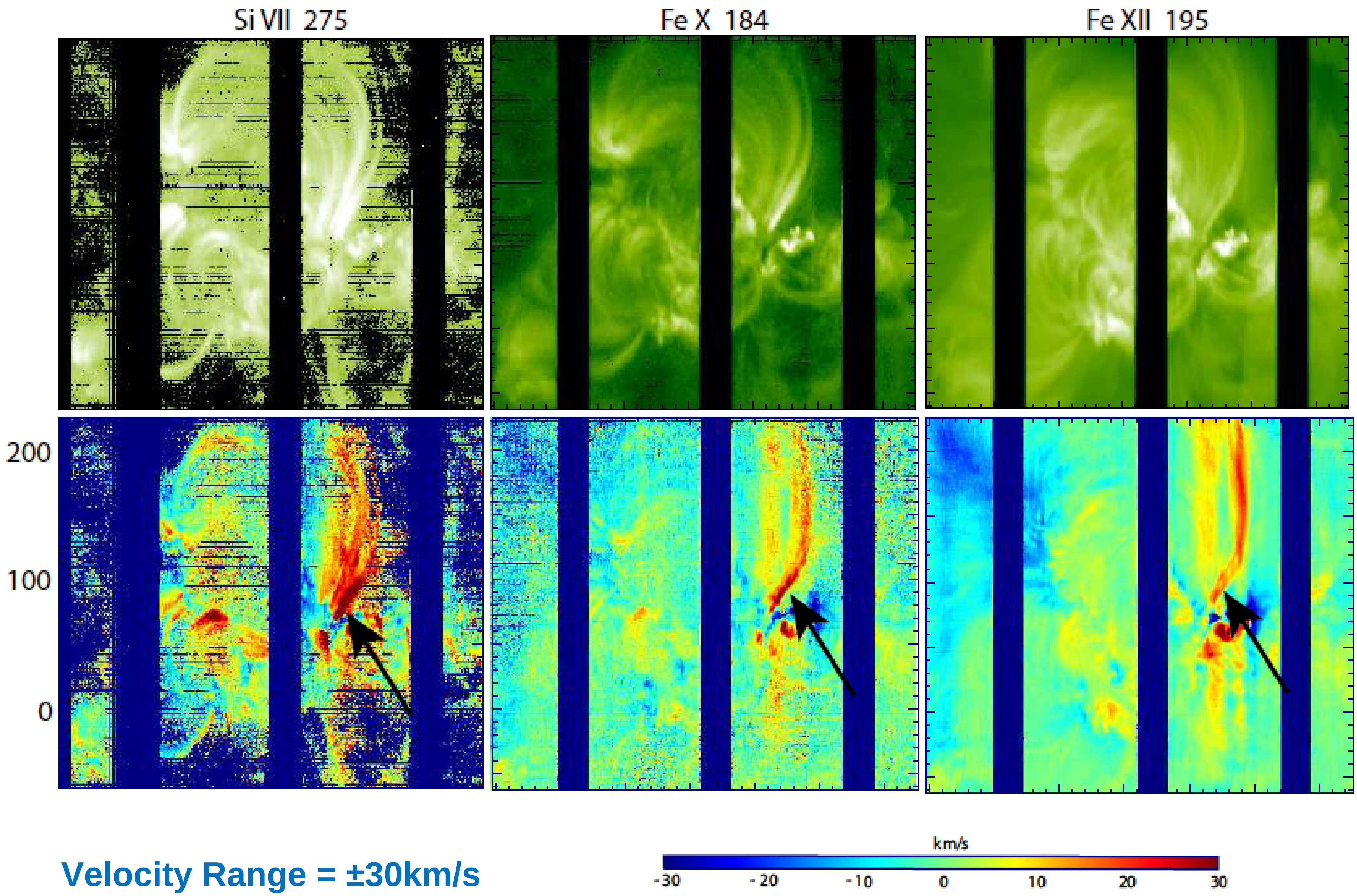
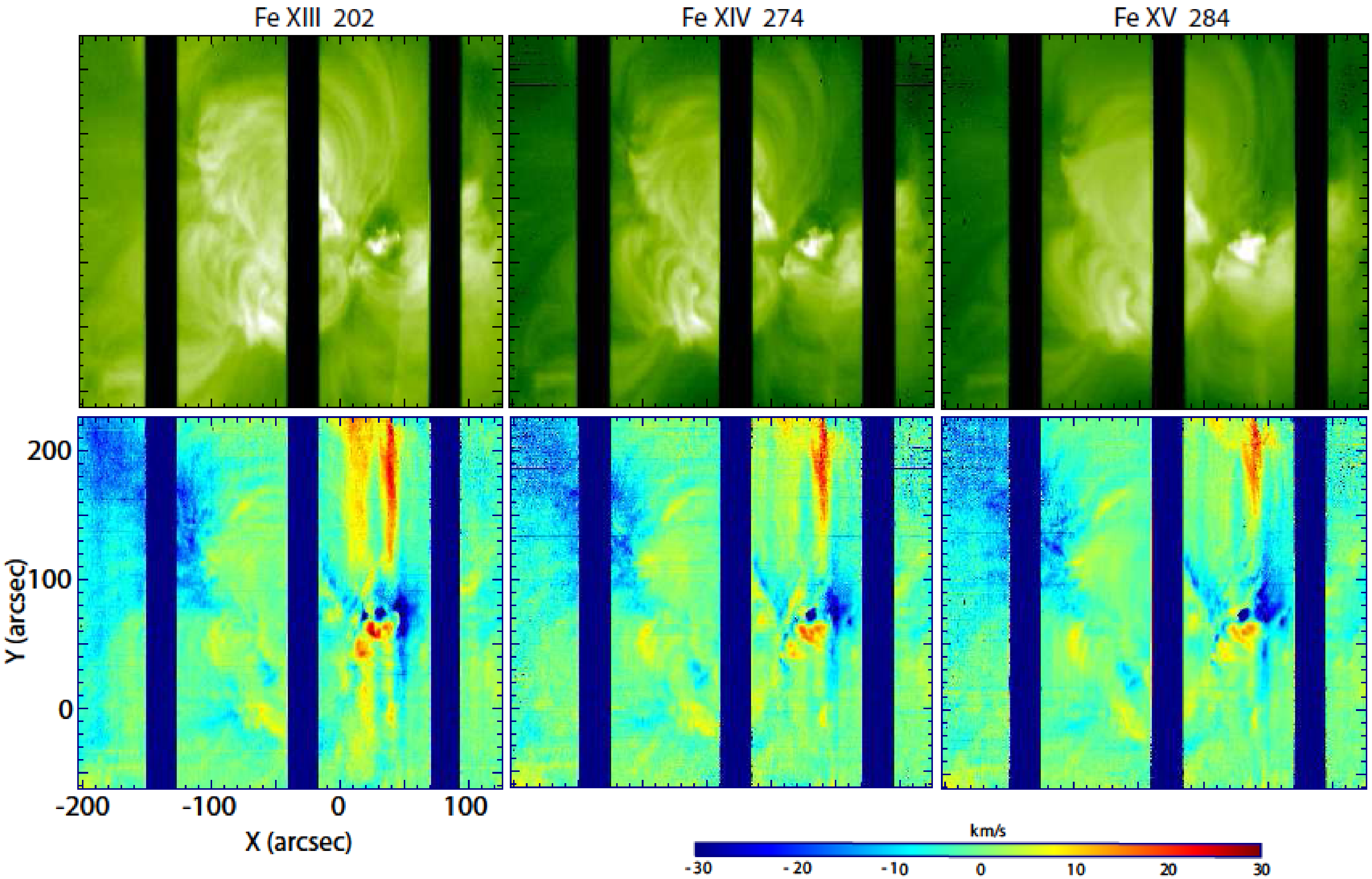
Ion / wavelength	log T [MK]	log Ne (cm^{-3})
Fe VIII (185)	5.6	
Mg VII (278)	5.8	**8.0 – 10.5**
Mg VIII (280)	5.8	
Si VIII (275)	5.8	
Fe X (184)	6.0	
Fe XII (195)	6.1	**7.0 – 12.0**
Fe XII (186)	6.1	
Si X (258)	6.1	**8.0 – 9.8**
Si X (261)	6.1	
Fe XIII (202)	6.2	**8.0 – 10.5**
Fe XIII (203)	6.2	
Fe XIV (264)	6.3	**8.5 – 11.0**
Fe XIV (274)	6.3	
Fe XV (284)	6.4	

Overall intensity and flow structure



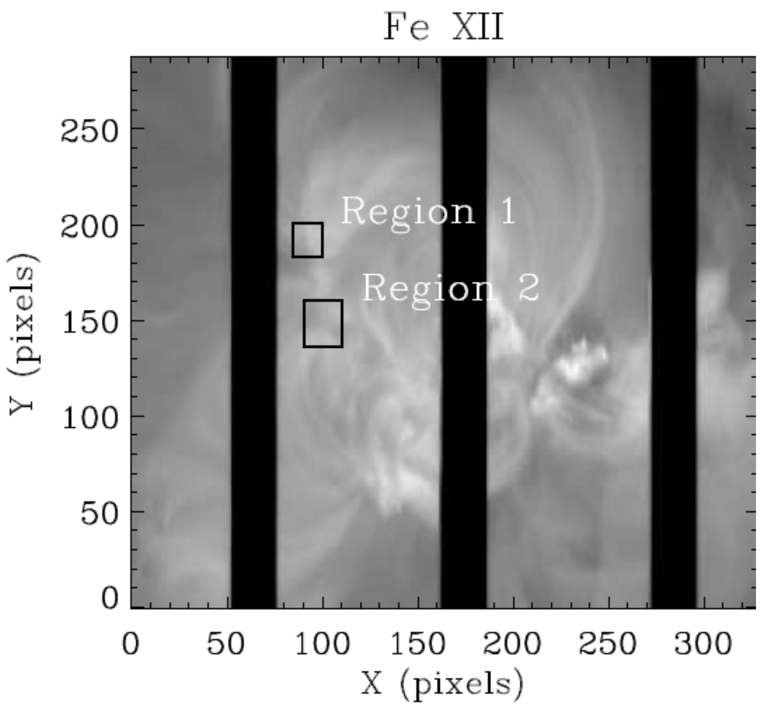
Velocity Range = ±30km/s

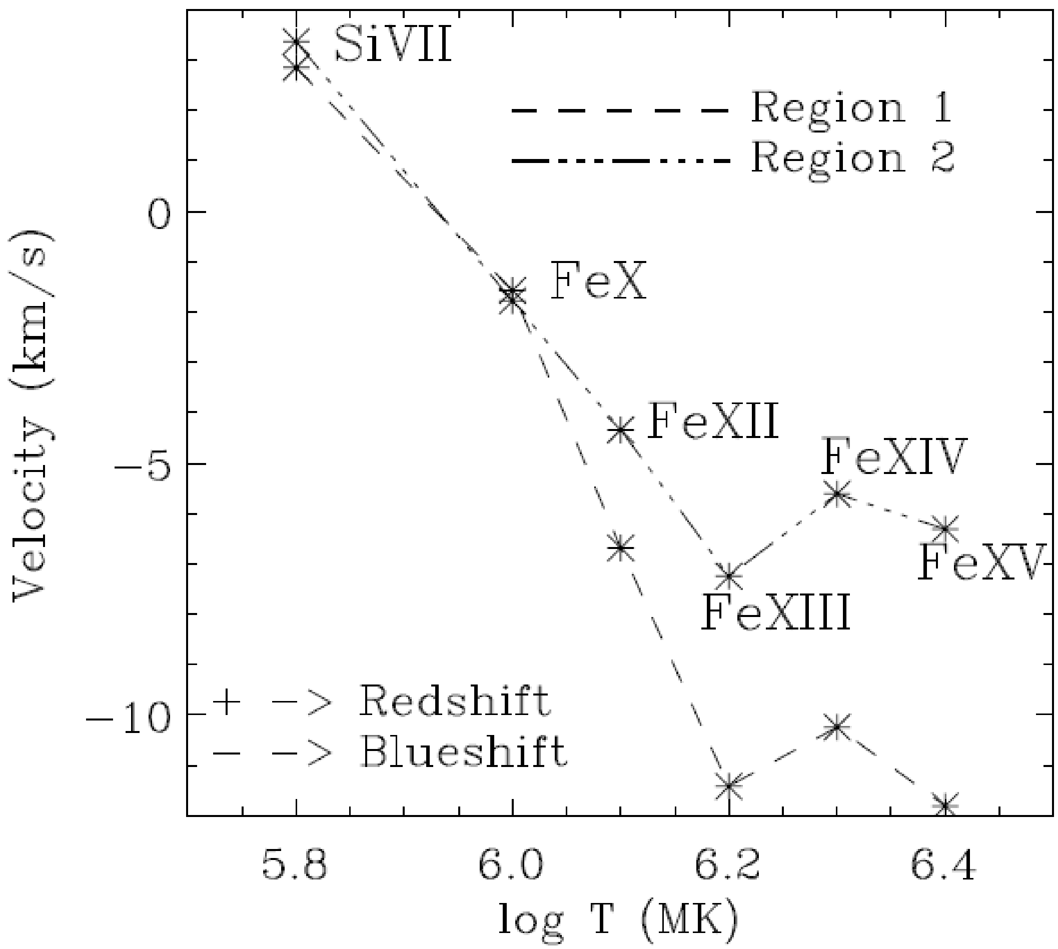
Overall intensity and flow structure



Velocity Range = ±30km/s

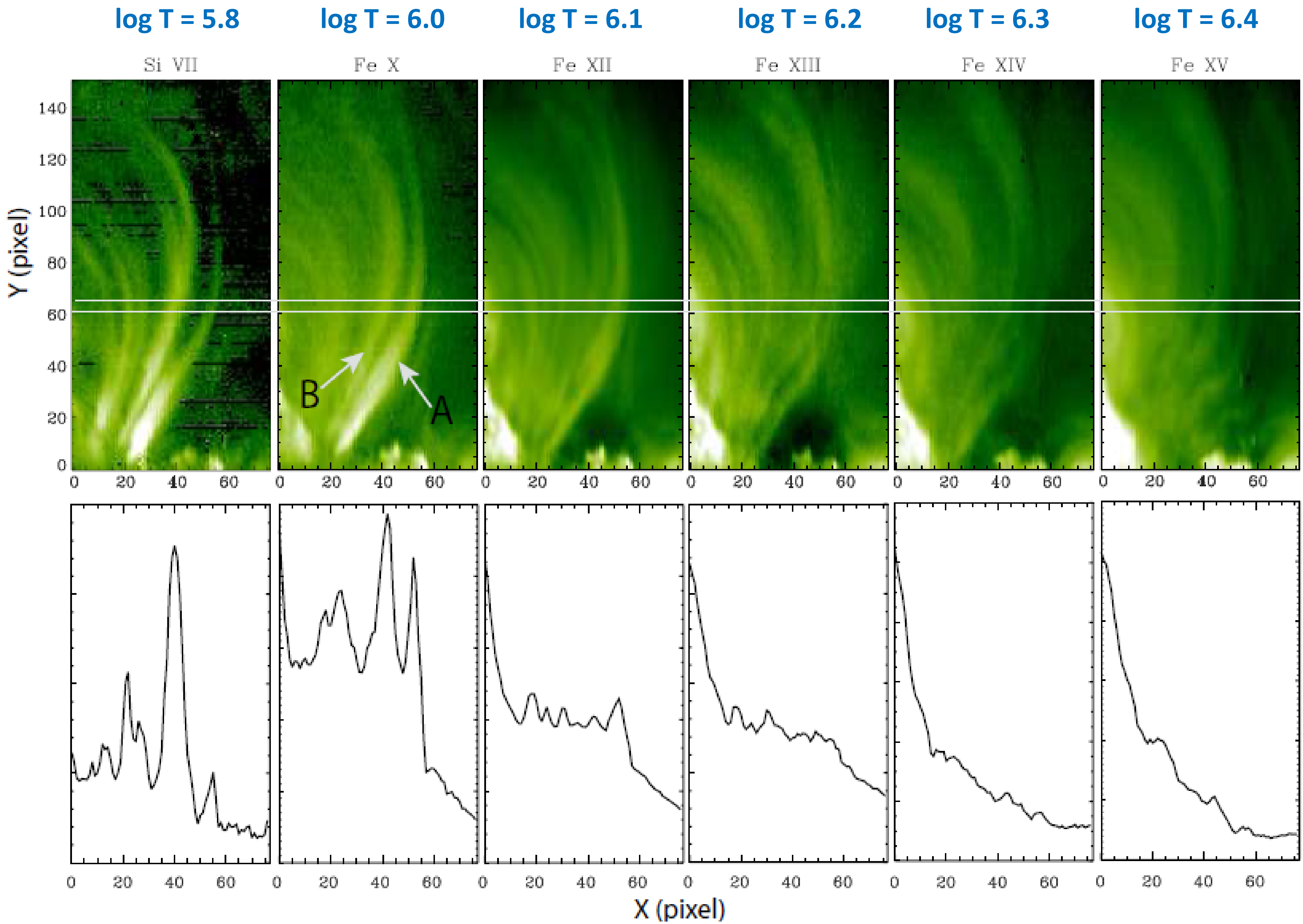
Flows at foot points of loops



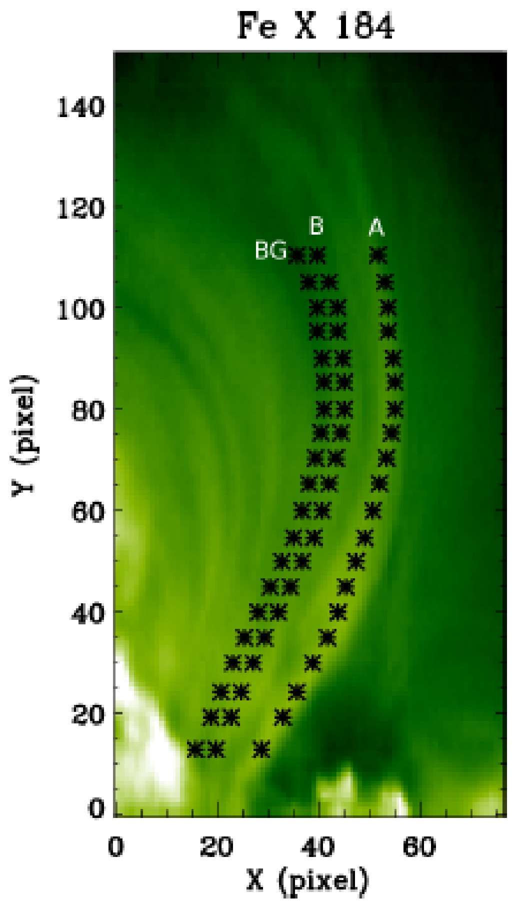


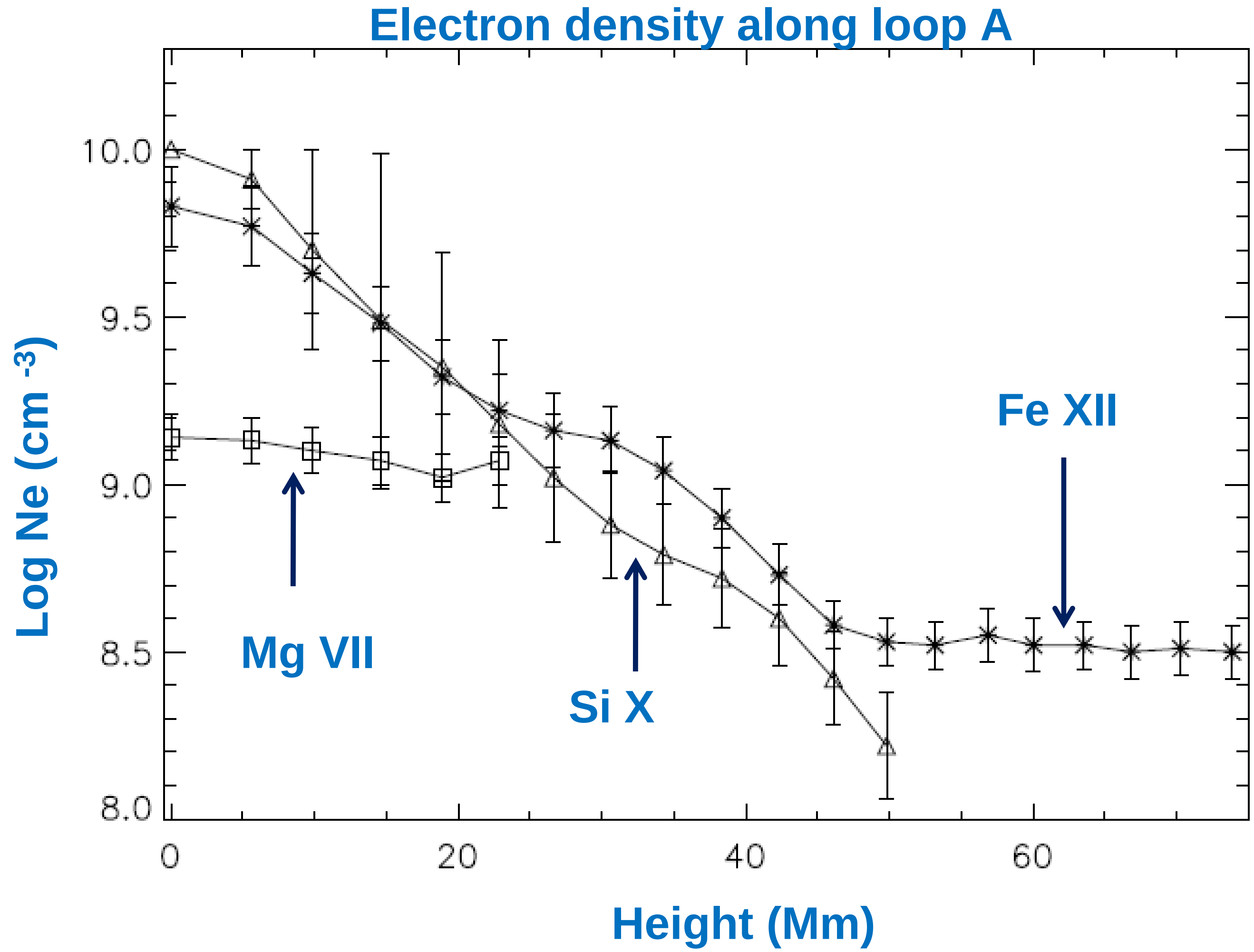
The foot point regions show red-shifted emission at lower temperatures. However, blue shifts dominate at high temperatures.

Intensity variation across loop structures



Densities along the loop





BG→ Background

Similar values for densities were obtained for loop B.

Filling factor along the loop

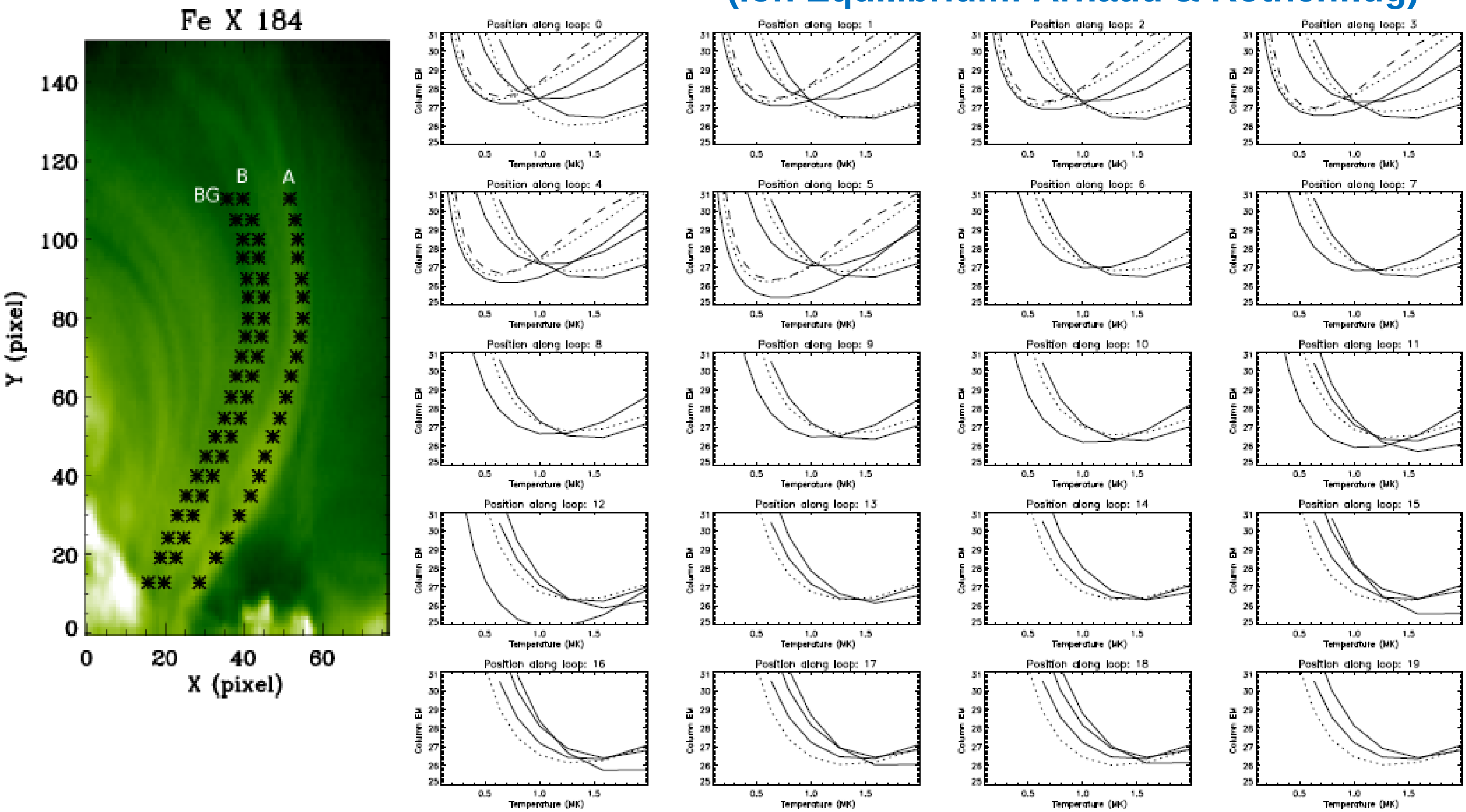
Filling factor $\Phi = EM / (h. N_e^2)$ (Porter & Klimchuk (1995), Cargill & Klimchuk (1997)

Height (Mm)	Fe XII h(″)	Fe XII N_e (cm^{-3})	Fe XII ϕ	Si X N_e (cm^{-3})	Si X ϕ	Mg VII h(″)	Mg VII N_e (cm^{-3})	Mg VII ϕ
0	7	9.83	0.02	10.00	0.00	20	9.14	1.79
5	8	9.77	0.02	9.91	0.01	17	9.13	1.71
9	6	9.63	0.06	9.70	0.06	15	9.10	1.48
14	10	9.48	0.07	9.49	0.14	15	9.07	0.84
18	10	9.32	0.15	9.35	0.26	15	9.02	0.56
22	13	9.22	0.20	9.18	0.43	10	9.07	0.28
26	12	9.16	0.29	9.02	1.03	...	...	...
30	11	9.13	0.37	8.88	2.11	...	...	...
34	11	9.04	0.47	8.79	2.86	...	...	...
38	10	8.90	0.79	8.72	3.25	...	...	...
42	11	8.73	1.30	8.60	4.14	...	...	...
46	10	8.58	2.63	8.42	7.40	...	...	...
49	7	8.53	4.52	8.22	18.73	...	...	...
53	12	8.52	3.11	...	...	...	...	...
56	10	8.55	3.66	...	...	...	...	...
60	10	8.52	4.21	...	...	...	...	...
63	9	8.52	4.57	...	...	...	...	...
66	11	8.50	4.41	...	...	...	...	...
70	12	8.51	3.80	...	...	...	...	...
73	12	8.50	3.89	...	...	...	...	...

Temperature: EM-Loci

$EM[T_e] = I_{obs} / [A(b)\ G(N_e, T_e)]$

I_{obs} = Background removed observed intensities
A(b) = Abundances (Coronal Abundance)
G (N_e, T_e) = Contribution function
(Ion Equilibrium: Arnaud & Rothenflug)



Warren et al. (2008) showed that the loops are “mildly multi-thermal”.

Summary and Conclusion (1)

- In lower temperature lines red shifts (downflows) are seen all along the loop being strongest at foot points.

- For higher temperatures red shifts are seen near the loop top, but turn to blue shifts towards the foot point.
  - **This is indicative of hot material evaporating and cool material condensing**.

Summary and Conclusion (2)

- The N_e along the loop decreased with increasing height. At a given location on the loop we obtained different densities, using spectral lines forming at different temperatures.
- We obtained a very low value of filling factor (0.02 – 0.05) at log T = 6.1 MK and a filling factor close to 1 at log T = 5.8 MK towards the foot point of the loop.
- The plasma in the loop along the LOS is "Mildly" MULTI-THERMAL (at least towards the foot point). The temperature increased from 0.8 to 1.5 MK from foot point to loop top.
    - **The loop is comprised of many unresolved strands which are being heated separately (?)**