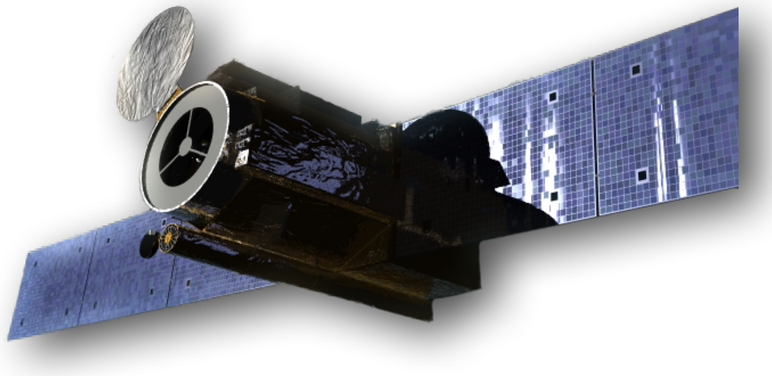
What determines active region plasma composition?

Hinode 15/IRIS 12 Meeting



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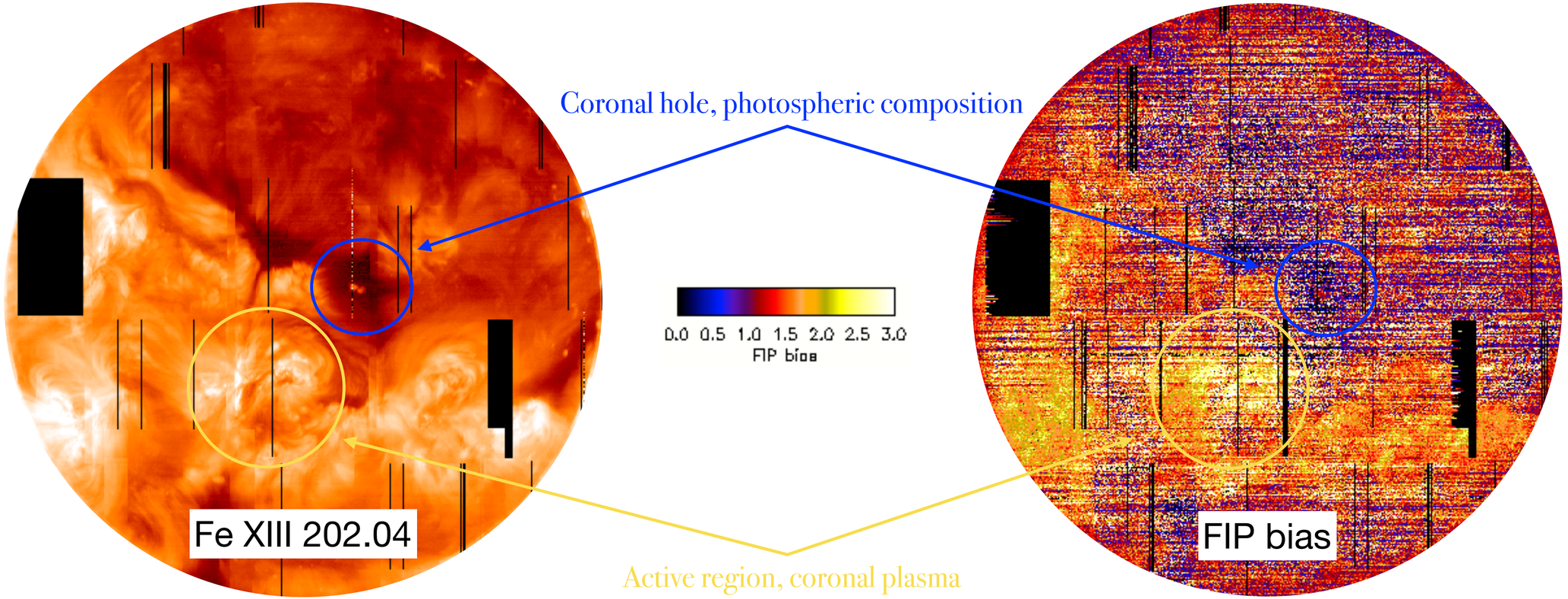
22 September 2022

Coronal plasma composition

$$\text{FIP}_{\text{bias}} = \frac{\text{coronal abundance}}{\text{photospheric abundance}}$$

= 1, i.e. photospheric composition (e.g. coronal holes, fast solar wind)

> 1, i.e. coronal composition (e.g. active regions, slow solar wind)

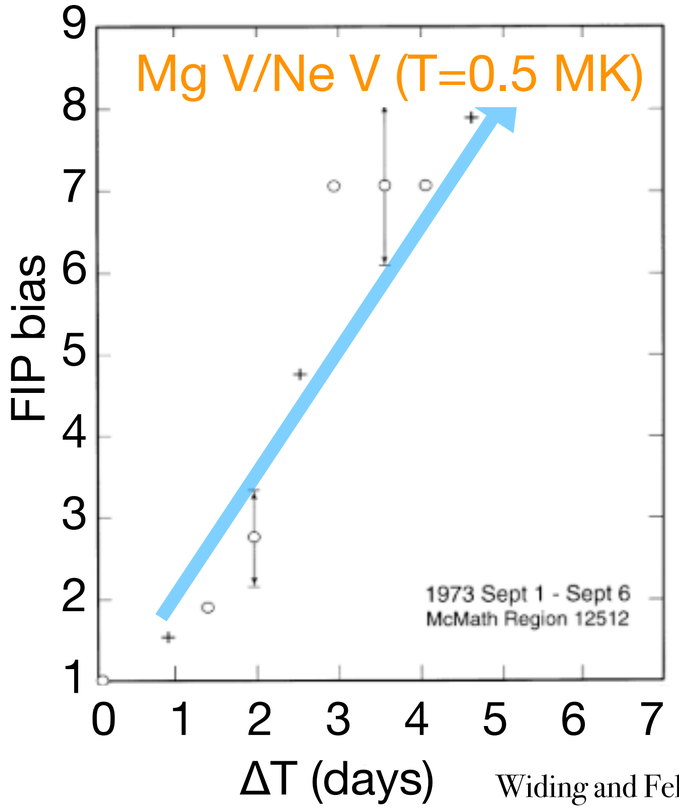


Strongest FIP effect in active regions - but is it the same in all active regions?

Composition variation in active regions

Emergence phase

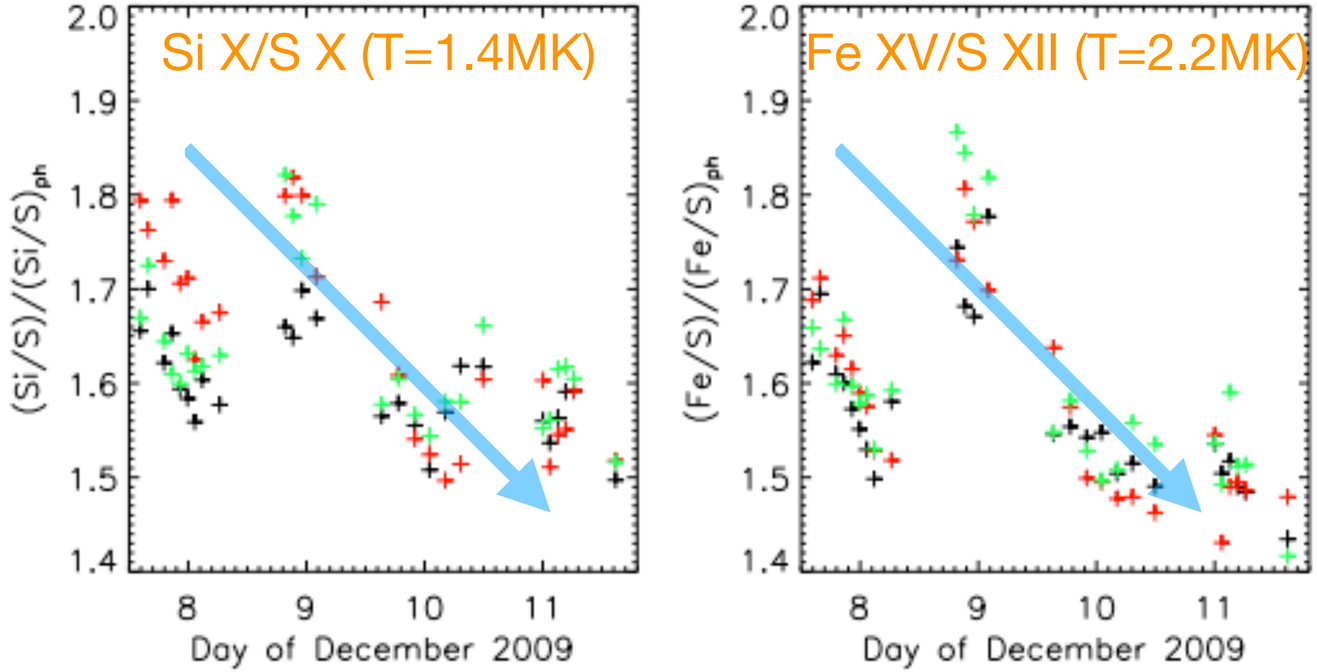
- reconnection, heating, reconfiguration of the field
- FIP bias increases (Widing and Feldman, 2001)



Widing and Feldman (2001)

Decay phase

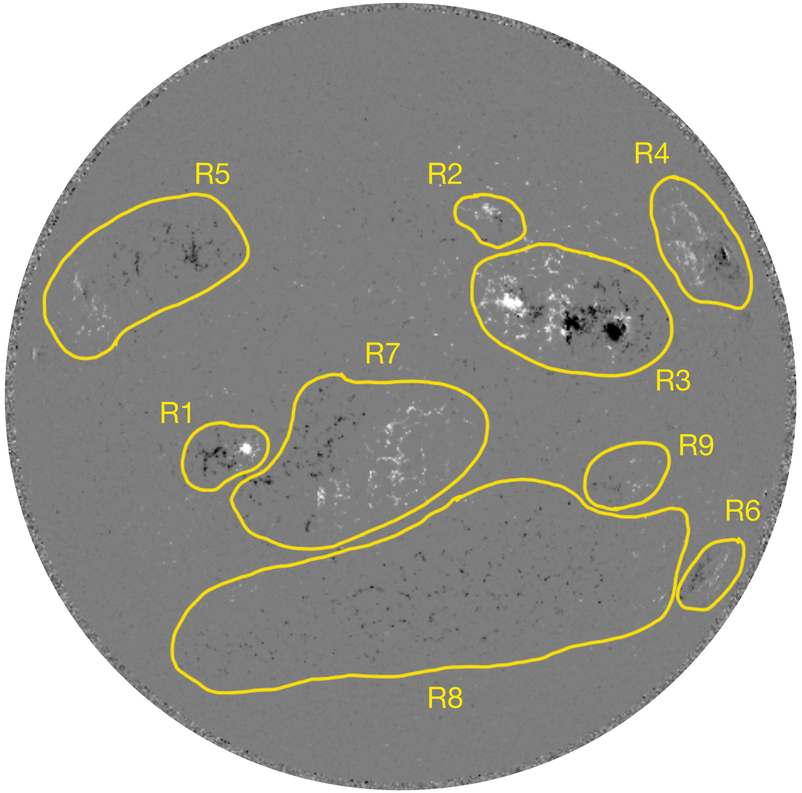
- Field dispersal, less heating, small bipole emergence
- FIP bias decreases (Baker et al., 2015)



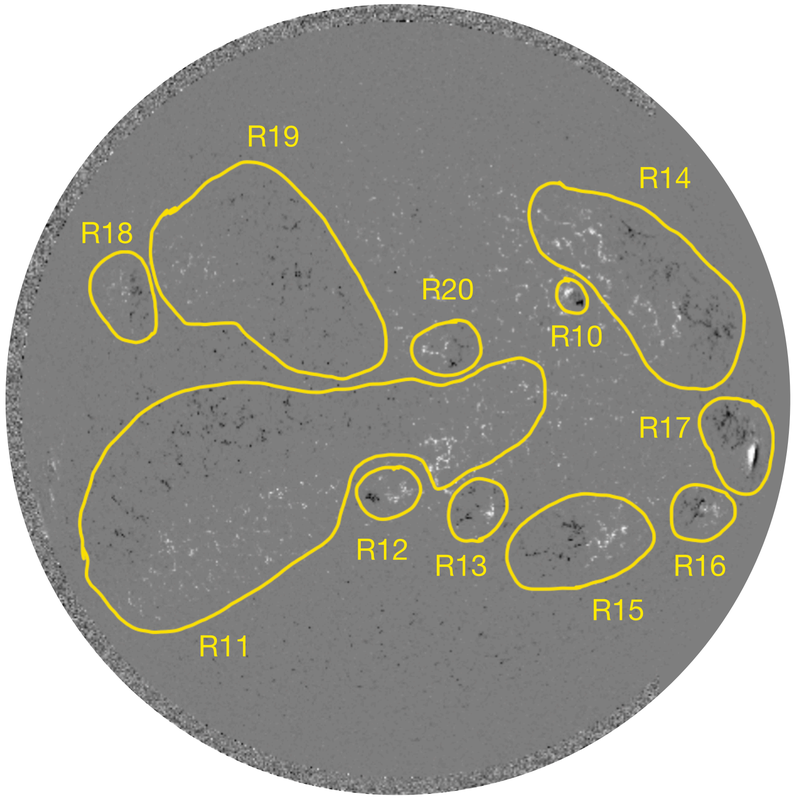
Ko et al. (2016)

Active region survey

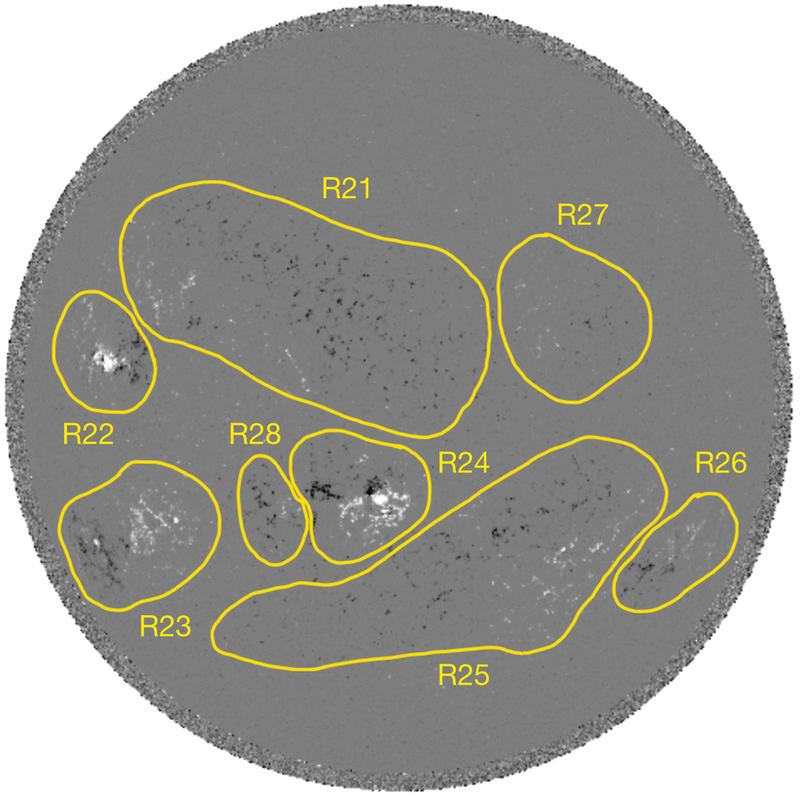
- 3 EIS full Sun composition scans
- 28 active regions
- Ages 0.5 to 189 days
- Magnetic flux: (100 – 3,640) × 10^{19} Mx (small and large ARs)



Scan 1



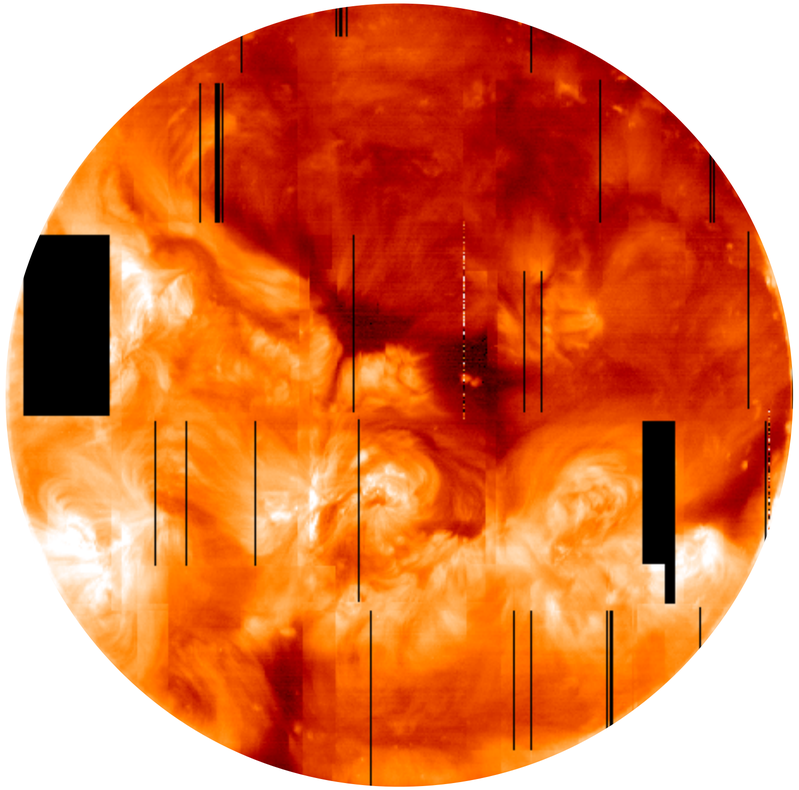
Scan 2



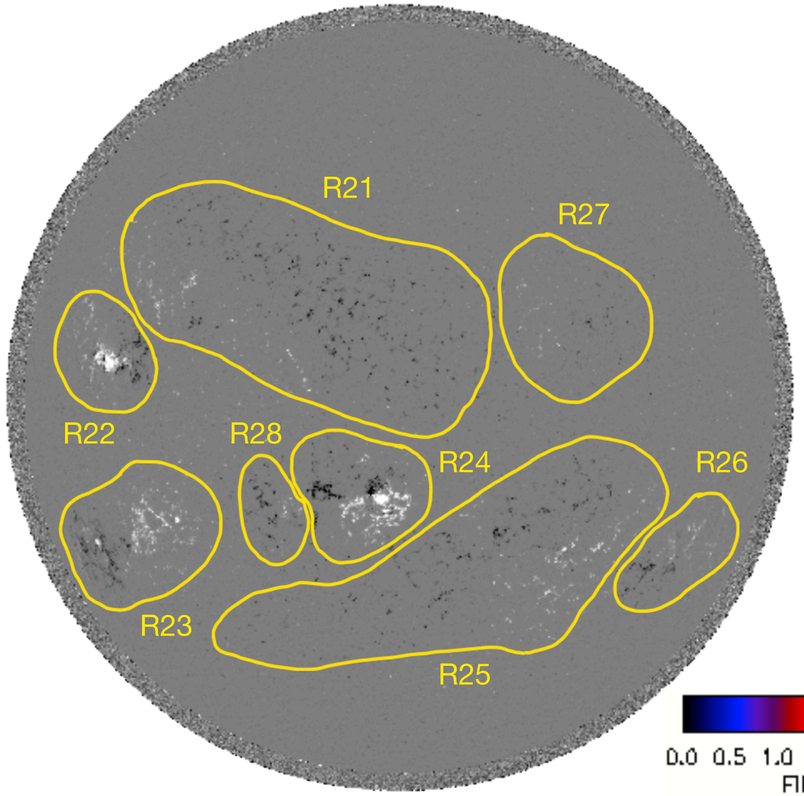
Scan 3

EIS observations

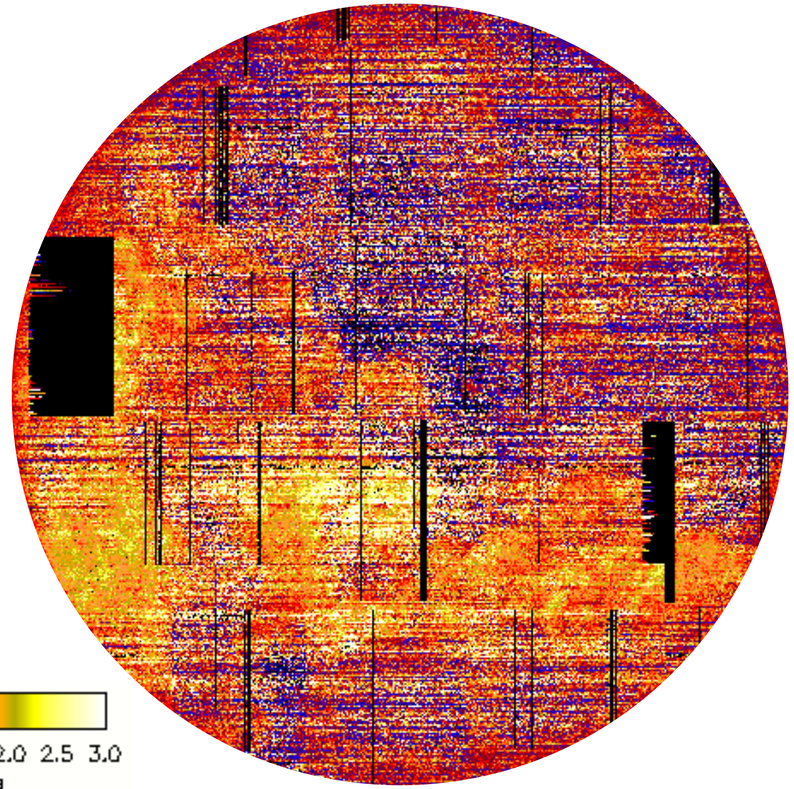
18-20th October 2015 Fe XIII 202.04 Å intensity



18-20th October 2015 HMI LOS magnetic field



18-20th October 2015 FIP bias



Can we see any AR global trends?

FIP bias measurements:

- Si X 258.38 Å/S X 264.23 Å ratio (+DEM analysis)
- plasma temperature of $\log T \approx 6.0 - 6.2$

Results

1. Correlation to size and age?

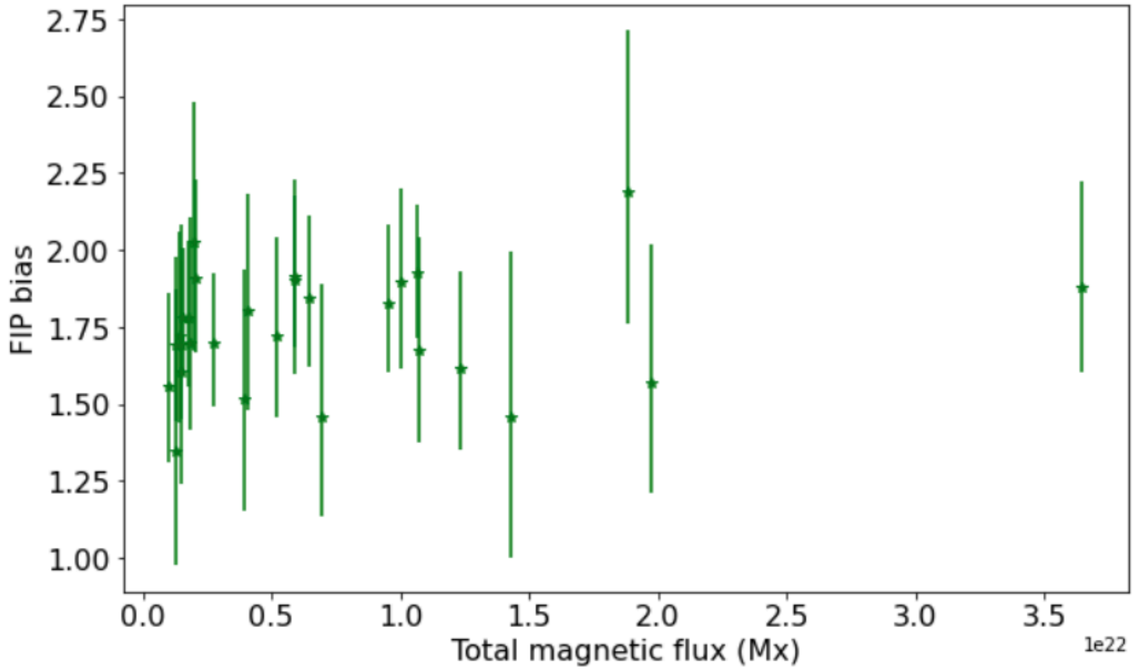
Magnetic flux range: $(100 - 3{,}640) \times 10^{19}$ Mx
FIP bias range: 1.4– 2.2

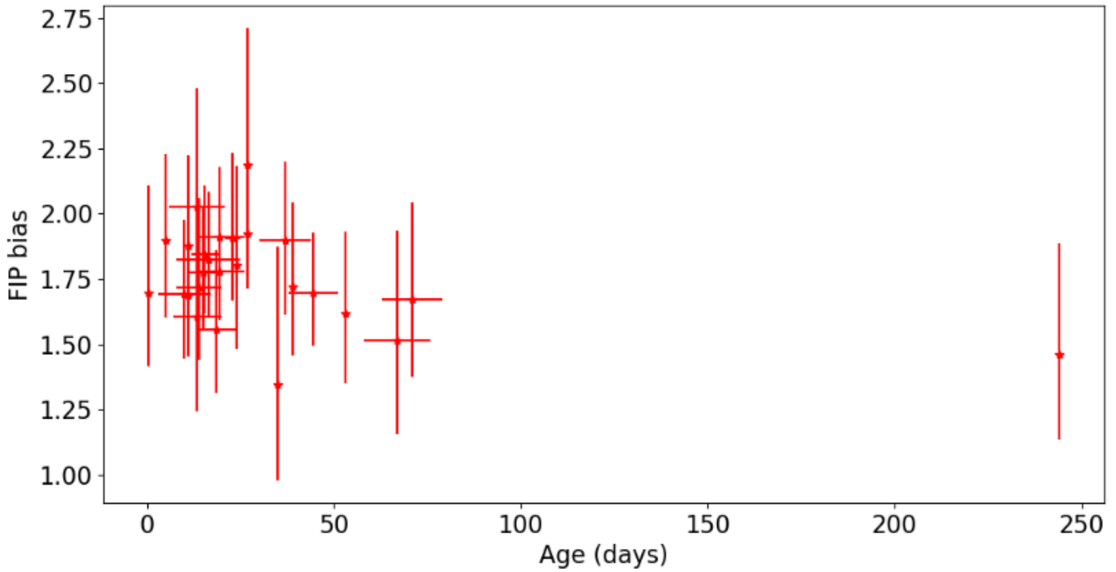
Magnetic flux range: $(1.3 - 380) \times 10^{19}$ Mx
FIP bias range: 1.2 - 2.0

Baker et al. (2018)

FIP bias is not dependent on the magnetic flux content of the active region.

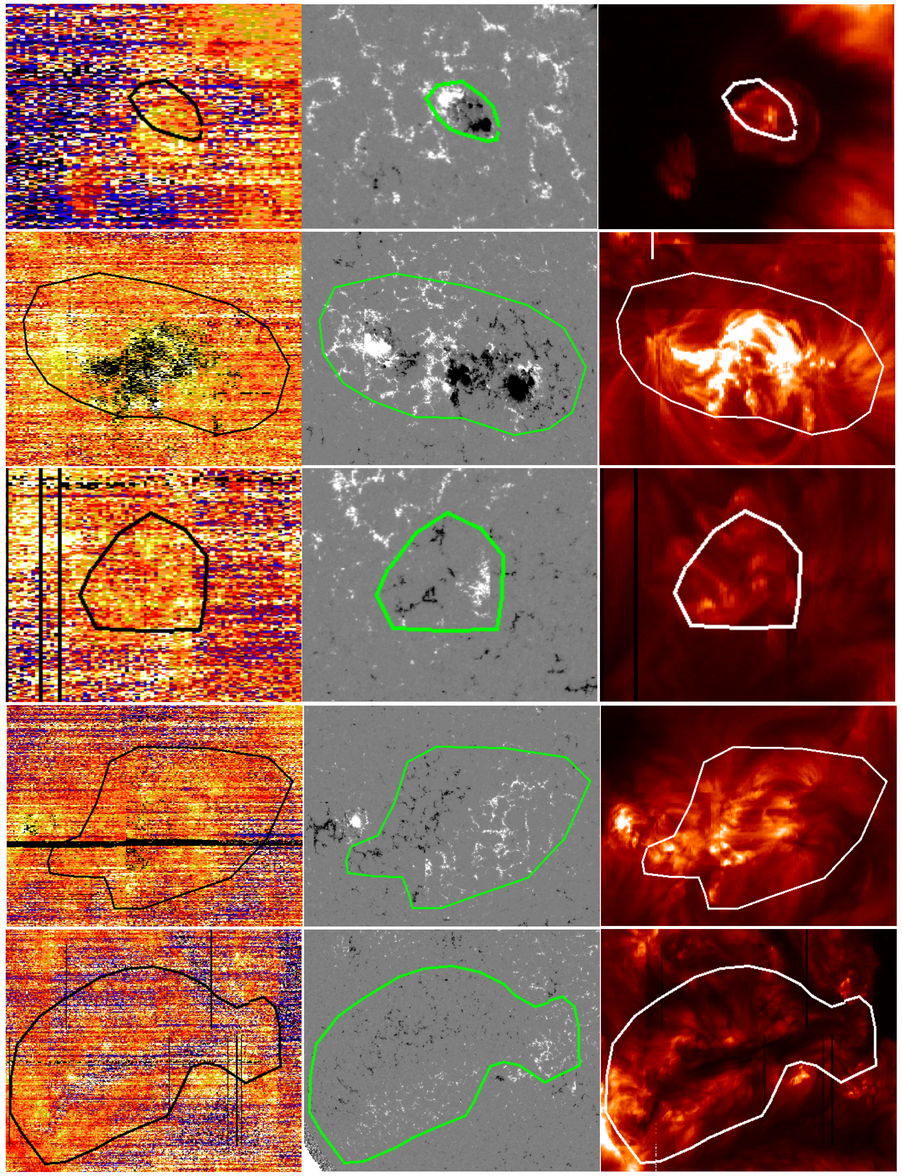
FIP bias does not follow a simple trend with age.





2. Correlation to evolutionary stage?

Active region evolution



Emerging active region
(median FIP bias = 1.7)

→ Relatively low FIP bias

Active regions with spots
(median FIP bias = 1.9 - 2.2)

→ Highest median FIP bias

Decayed active regions
(median FIP bias range = 1.6 - 2.0)

Extended, very dispersed active regions
(median FIP bias range = 1.4 - 1.8)

Active regions with filament channel
(median FIP bias range = 1.5 - 1.6)

→ Progressively lower median FIP bias

2. Correlation to evolutionary stage?

Low magnetic flux density regime:

increase in magnetic flux density

↓

stronger heating at chromospheric footpoints

↓

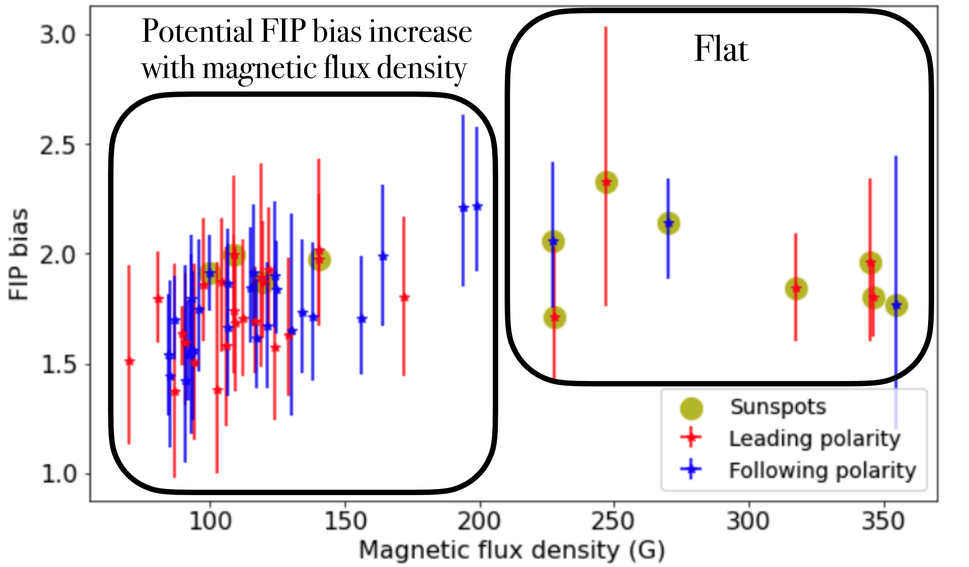
temperature at chromospheric height decreases

↓

more elements being ionized

↓

higher FIP bias



Active region evolution

High magnetic flux density regime:

increase in magnetic flux density

↓

convection is inhibited

↓

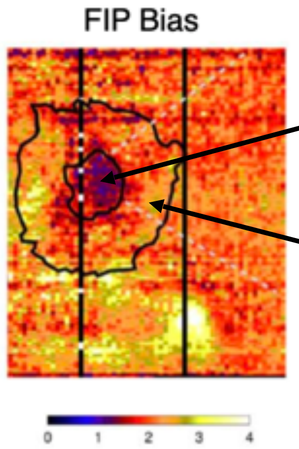
temperature at chromospheric height decreases

↓

fewer elements being ionized

↓

lower FIP bias

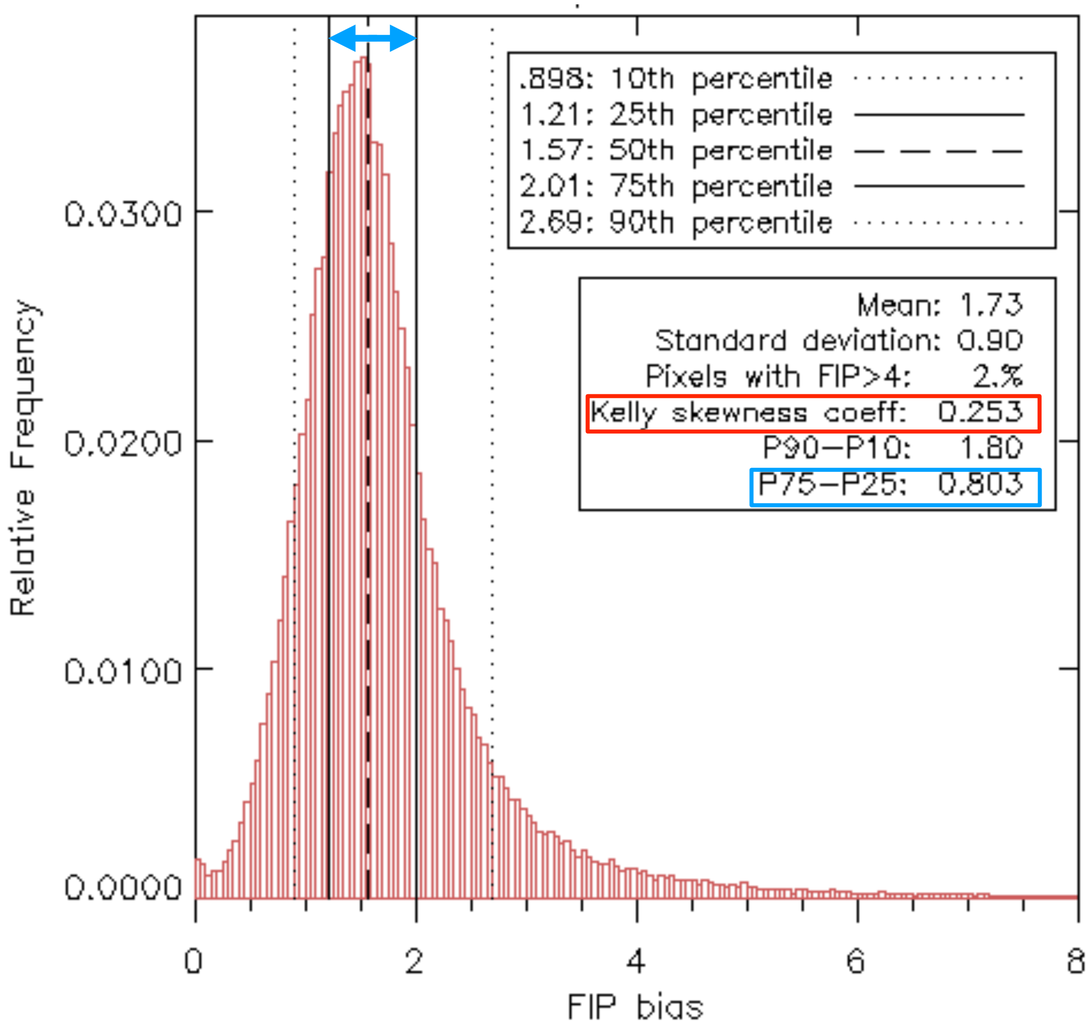


Sunspot umbra
- photospheric plasma

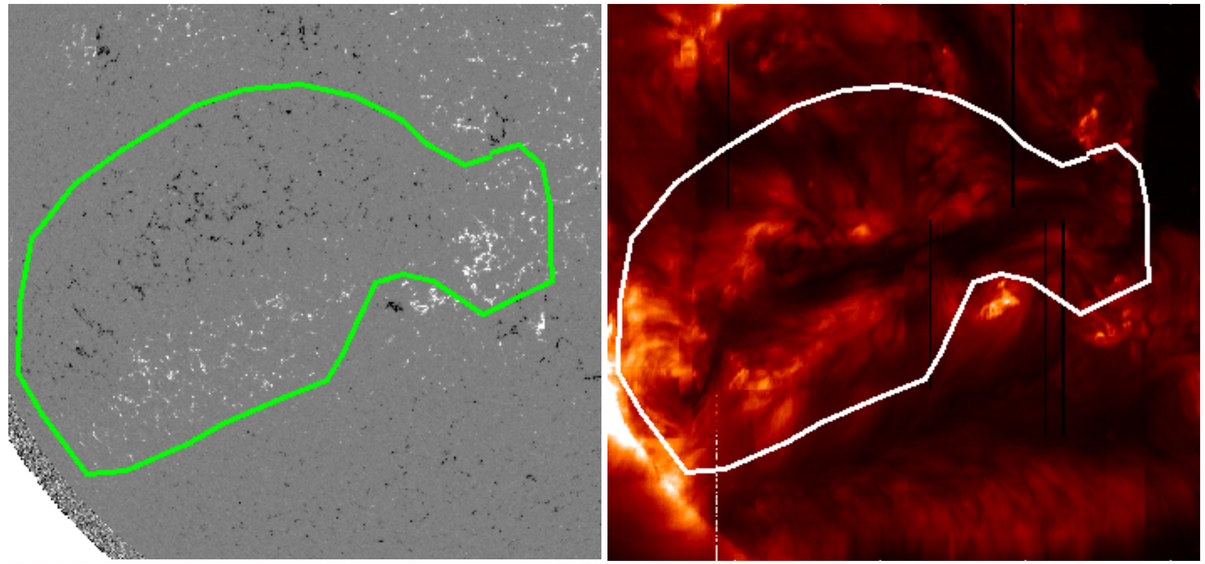
Sunspot penumbra
- coronal plasma

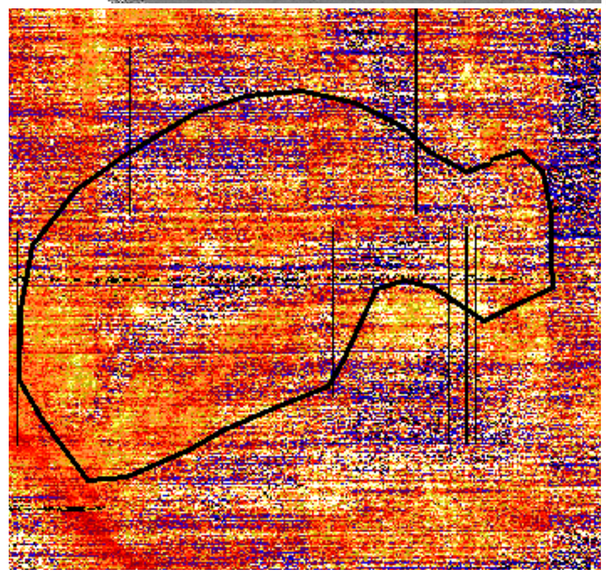
Baker et al. (2021)

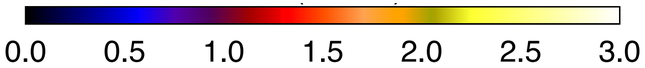
3. FIP bias distribution

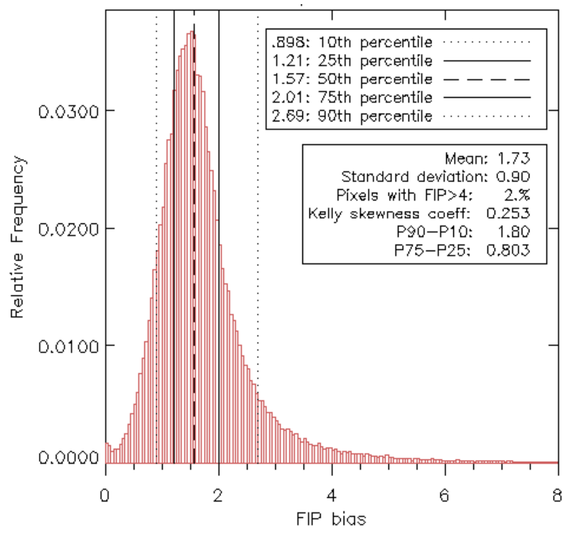


3. FIP bias distribution









Conclusions

- FIP bias is not correlated with total magnetic flux (size) or age of the active region
- FIP bias correlated with active region evolutionary stage
  - Supported by potential trend with magnetic flux density
- FIP bias has a significant spread → range of structures within an active region

Mihailescu et al. (2022)

What's next?

- Temporal evolution in one active region
- Look at substructures within the active region
- Two temperature diagnostics