Flux-flux relations as statistical proxies of unresolved small-loop like structures

Krzysztof Barczynski
Hardi Peter
Lakshmi Pradeep Chitta
Sami K. Solanki

Max Planck Institute for Solar System Research, Göttingen

MAX-PLANCK-GESELLSCHAFT

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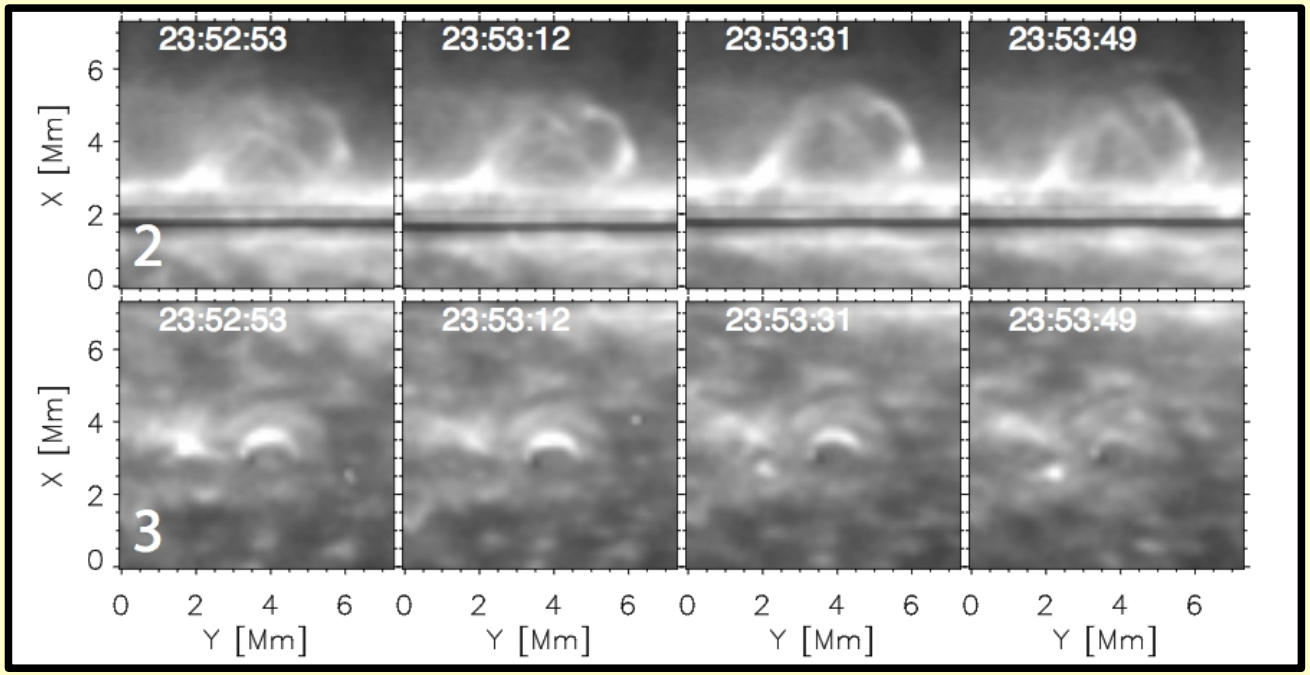
Hot and cool loops

small cool loops
$T \sim 10^5$K, L<10 Mm

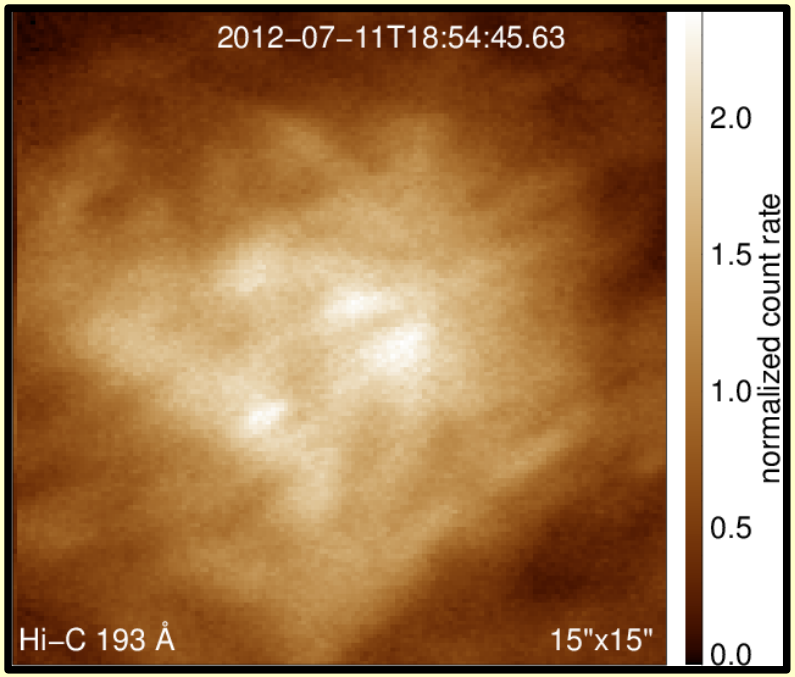


IRIS, SJI1400

Hansteen et al.(2014)

Chromosphere + TR

small hot loops(?)
$T > 10^6$K, L~1 Mm



Peter et al (2013) A&A 556, 104

Corona

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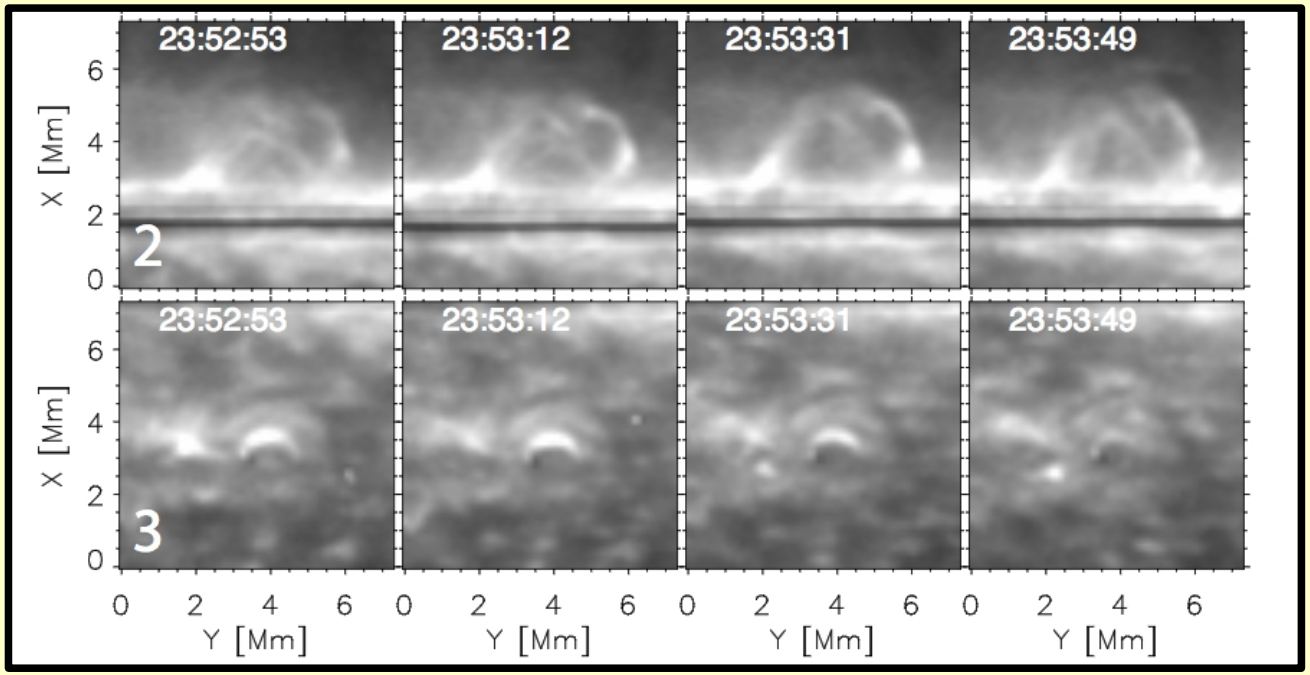

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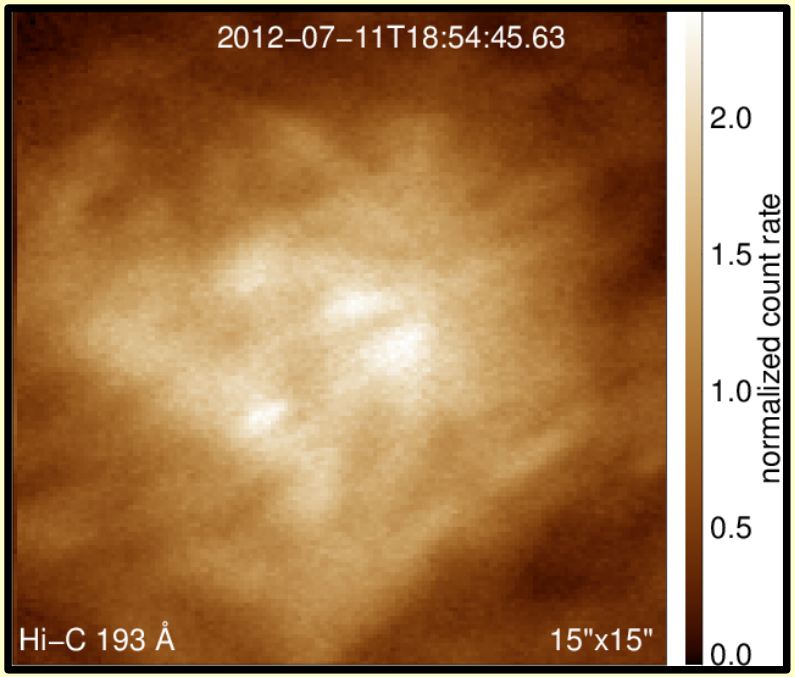


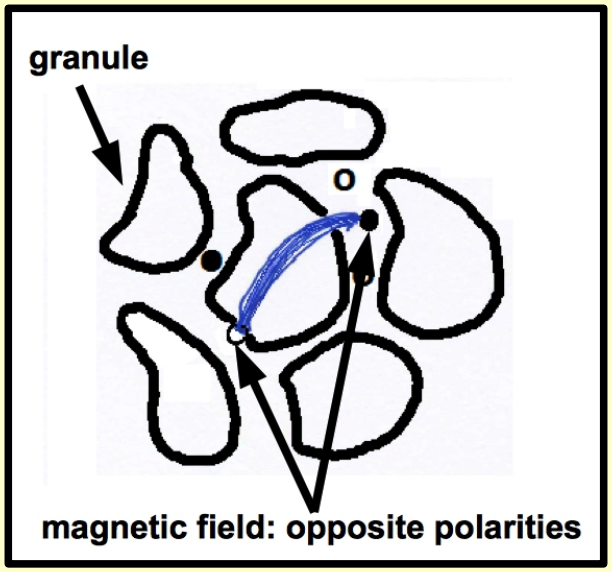
Peter et al (2013) A&A 556, 104

Corona

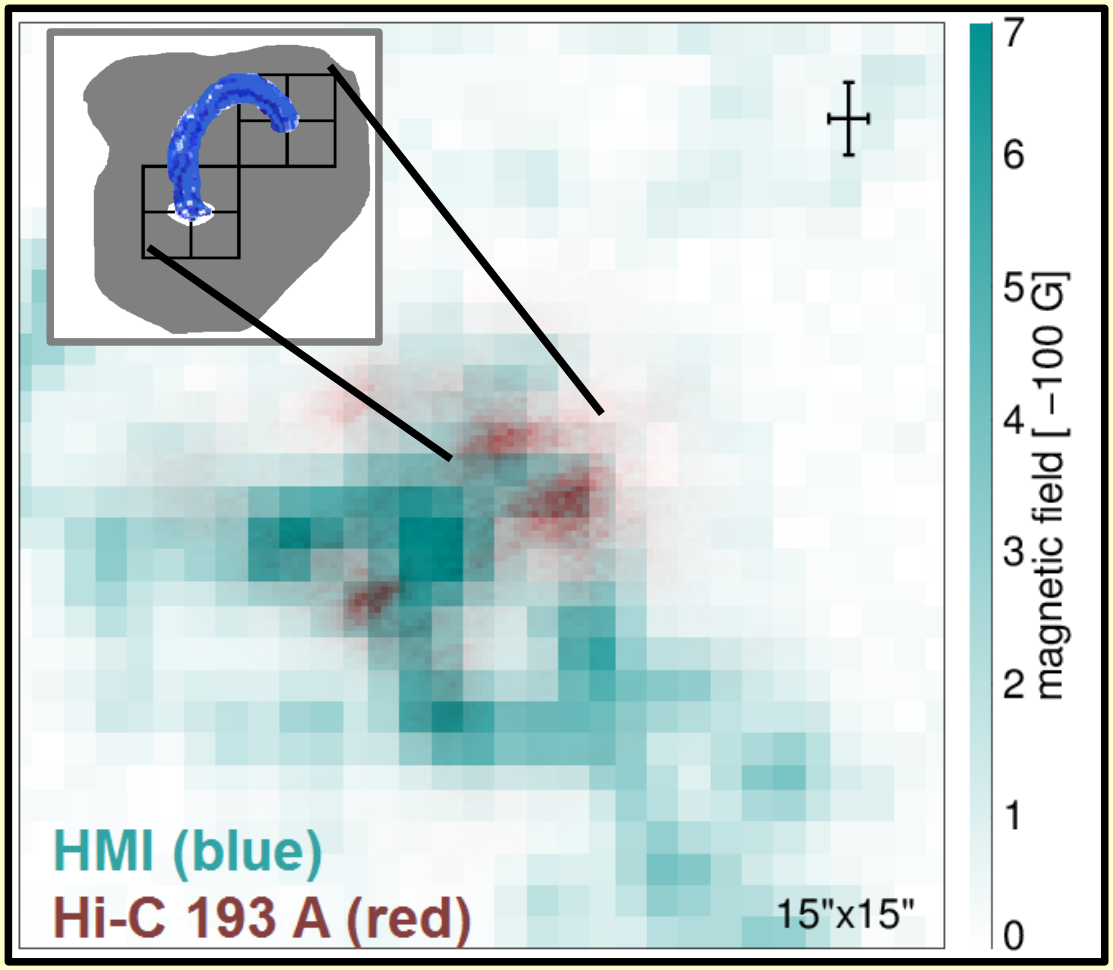
- Do small (~1Mm) hot (>1MK) loops exist?
- How do small-scale structures evolve?
- What is the relation between small structures and magnetic field?

Properties of miniature structures

- *lifetime:* minutes
- *length:* 1-2 Mm
- *aspect ratio:* 1.5-2.5



→ consistent with photospheric granular motions and sizes



Barczynski et al. (A&A 599, 137)

- consistent with "hidden" opposite polarities at HMI resolution

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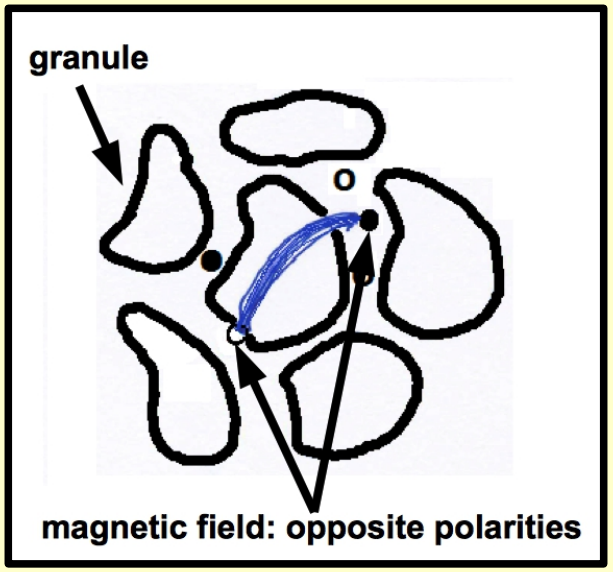

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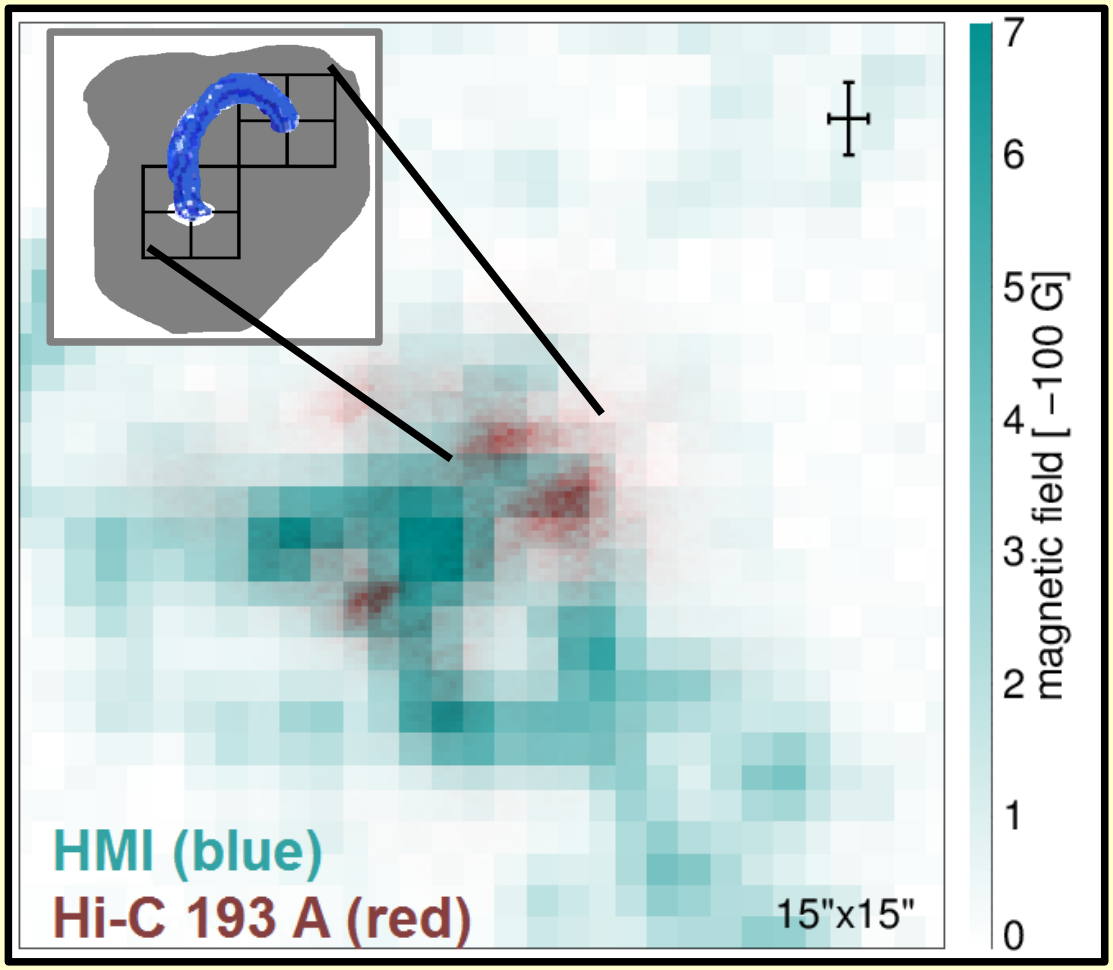

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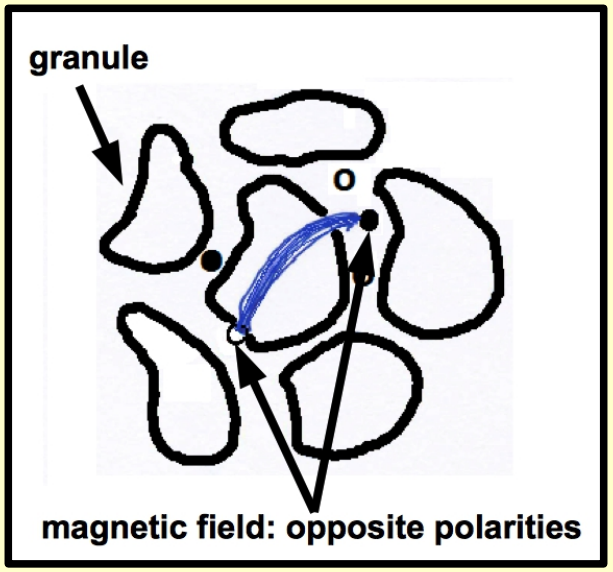

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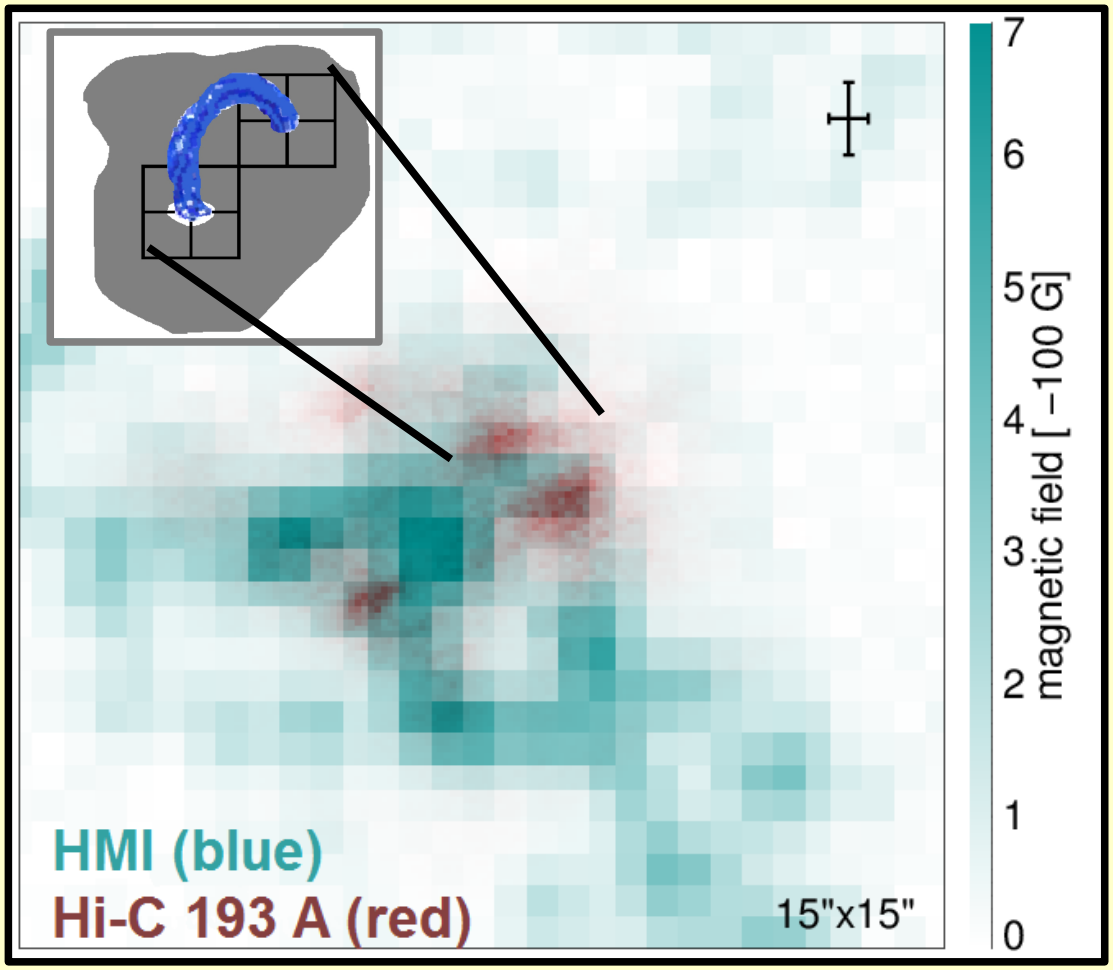

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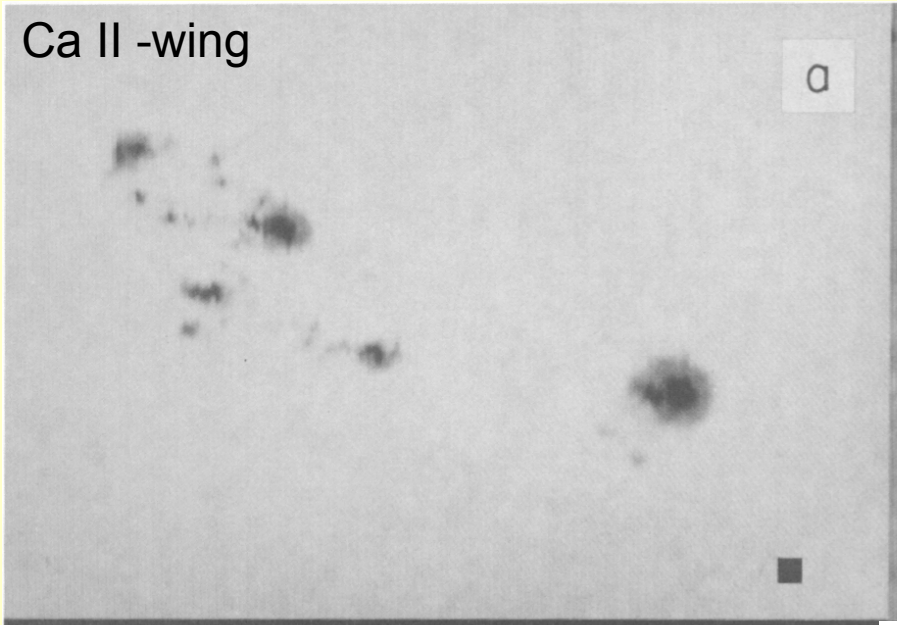
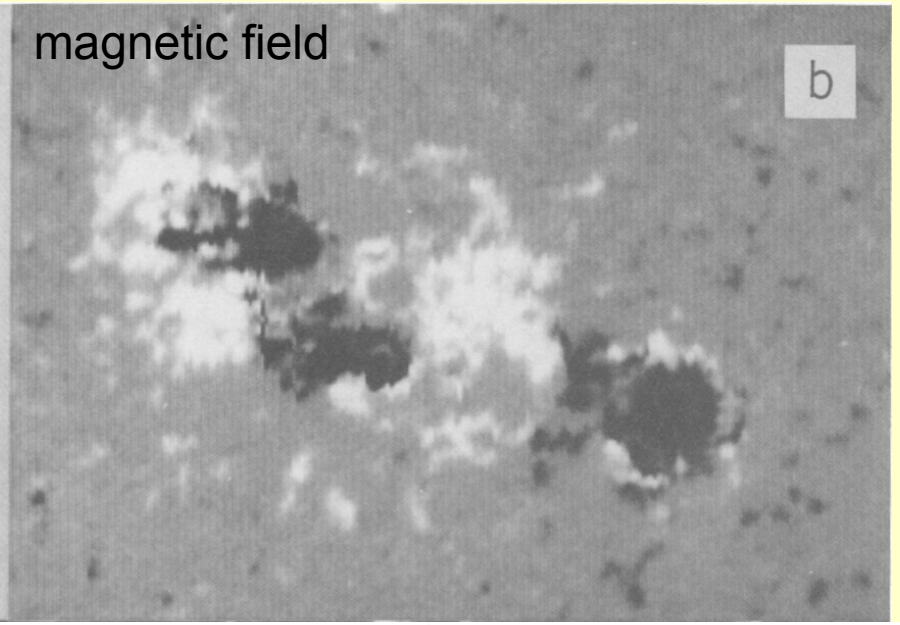
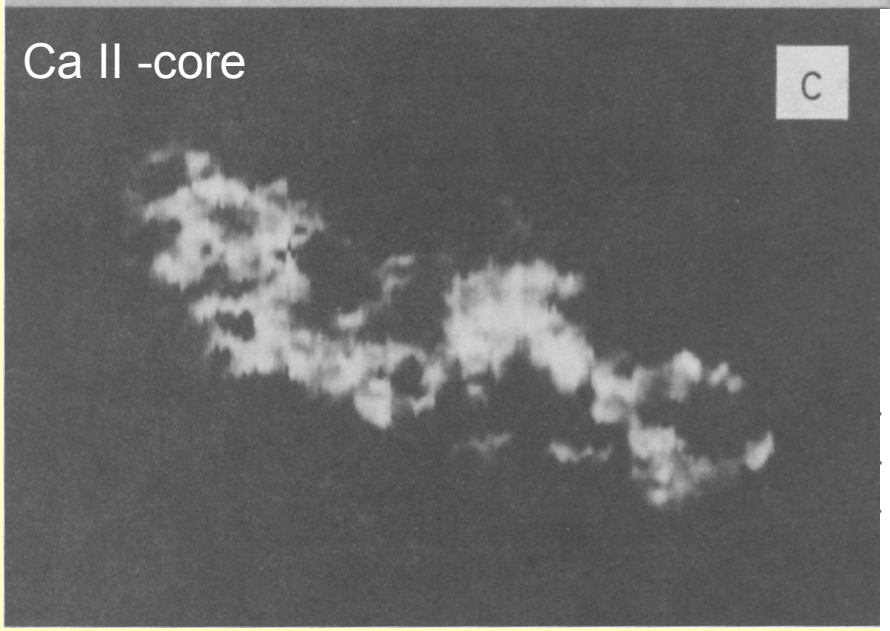
- How to investigate unresolved small-loops?

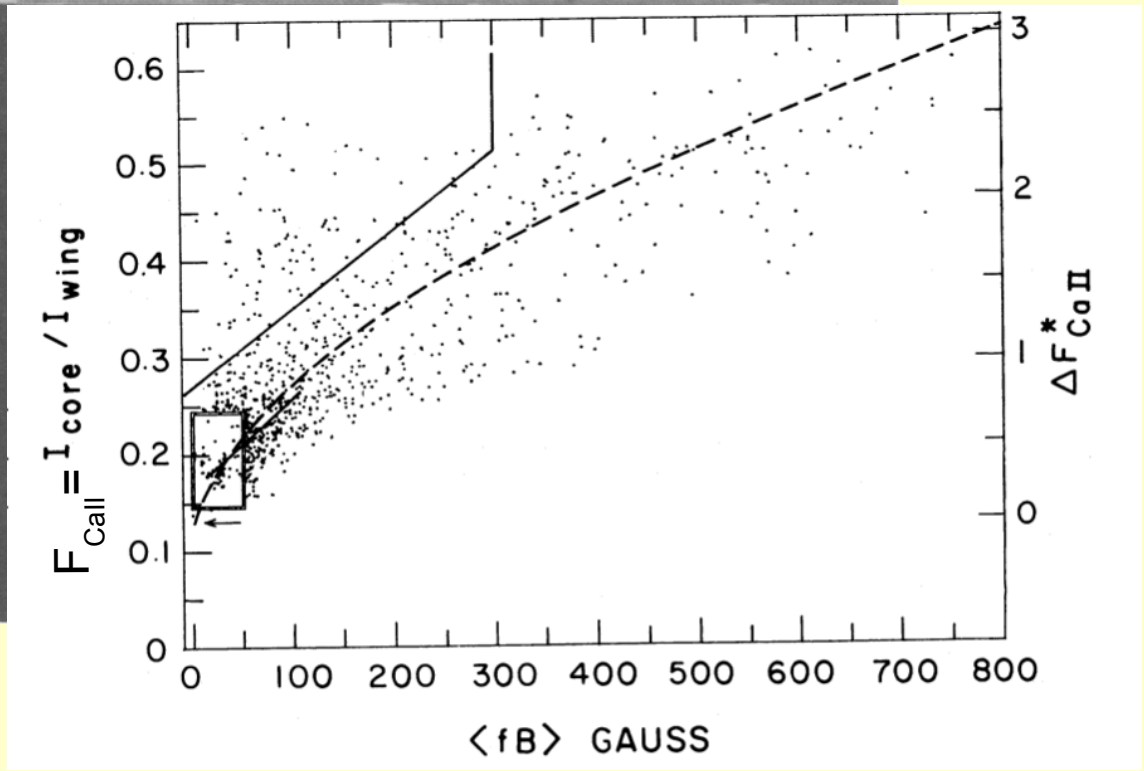
→ statistical study of the flux-flux relation

Magnetic field vs. Ca II intensity









Schrijver et al. (1989) ApJ 337, 964

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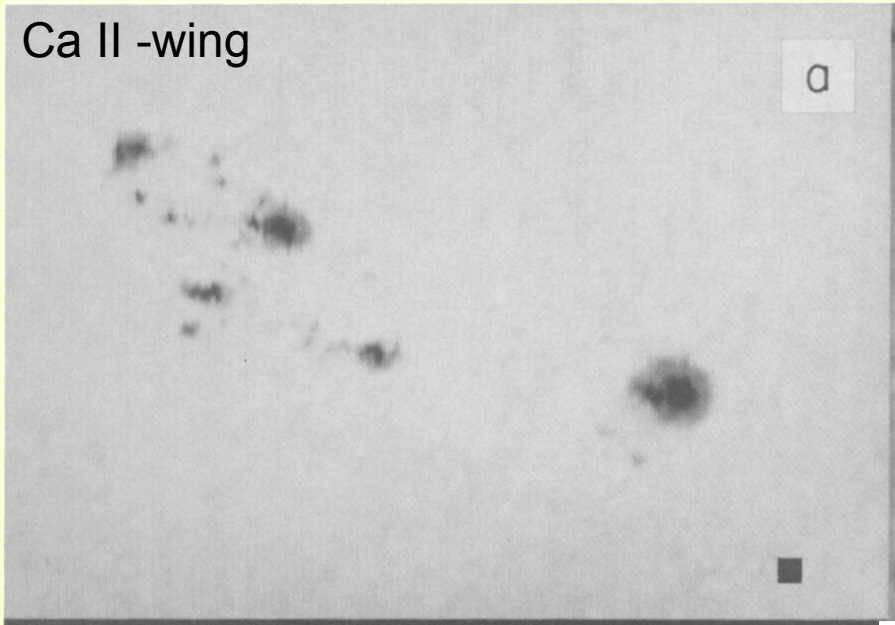

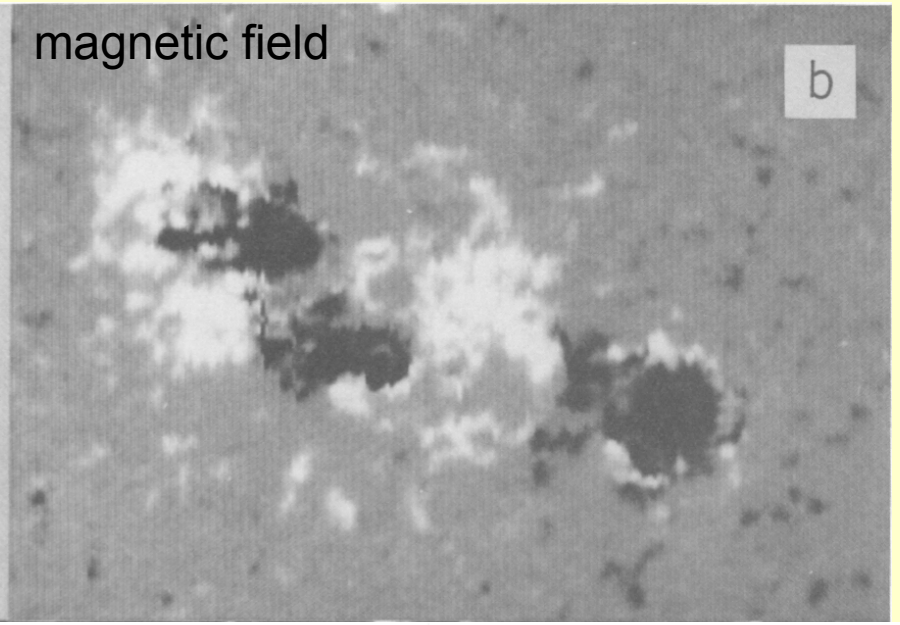

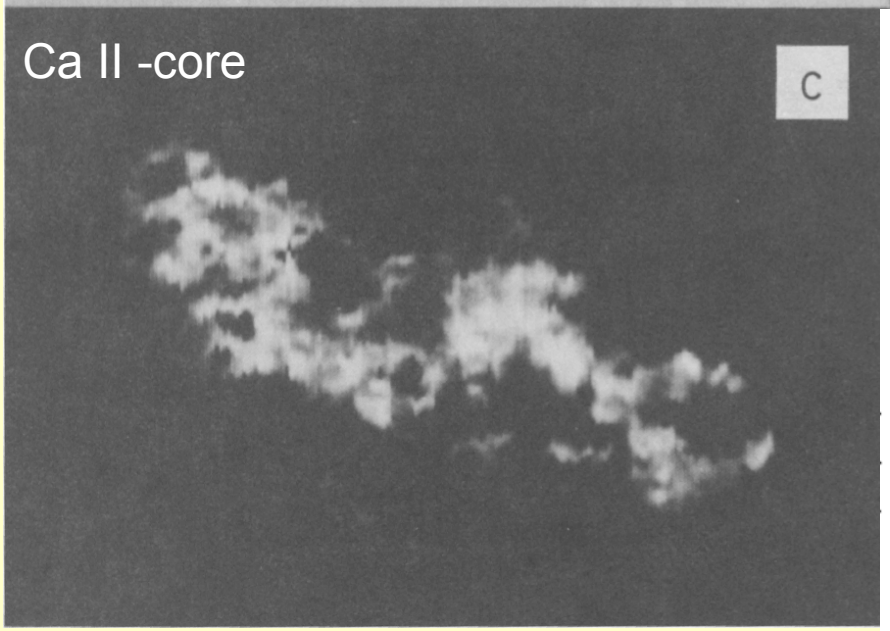

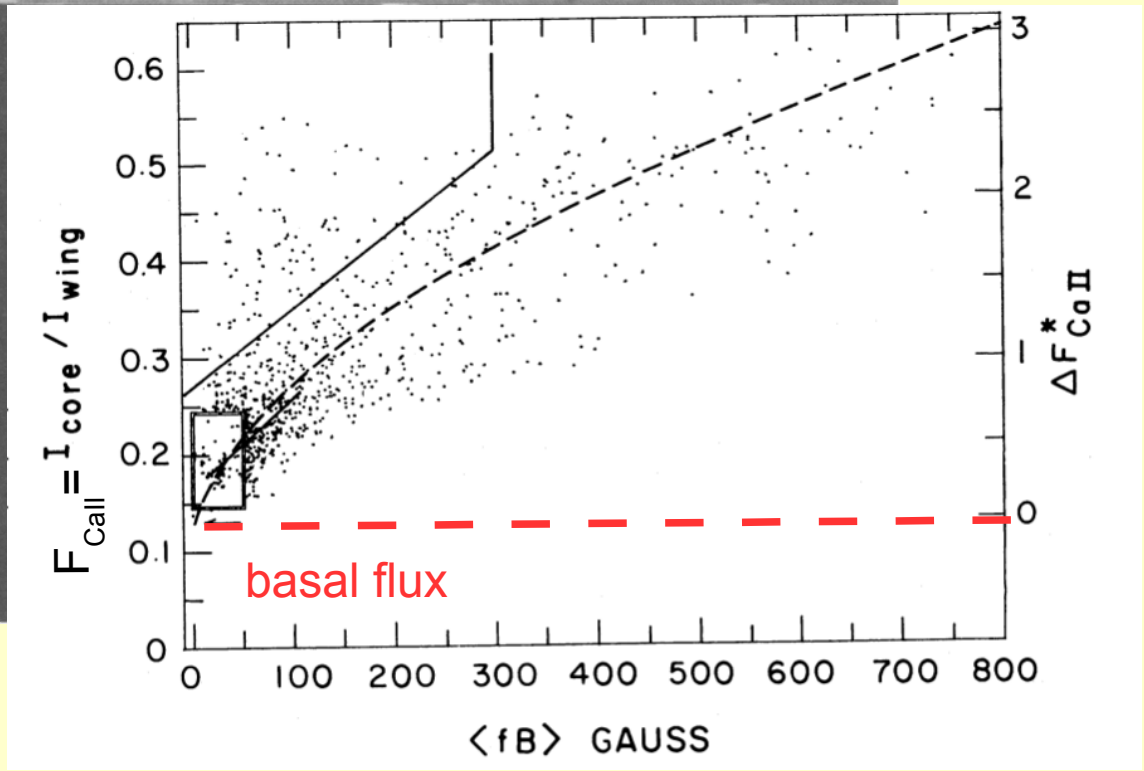

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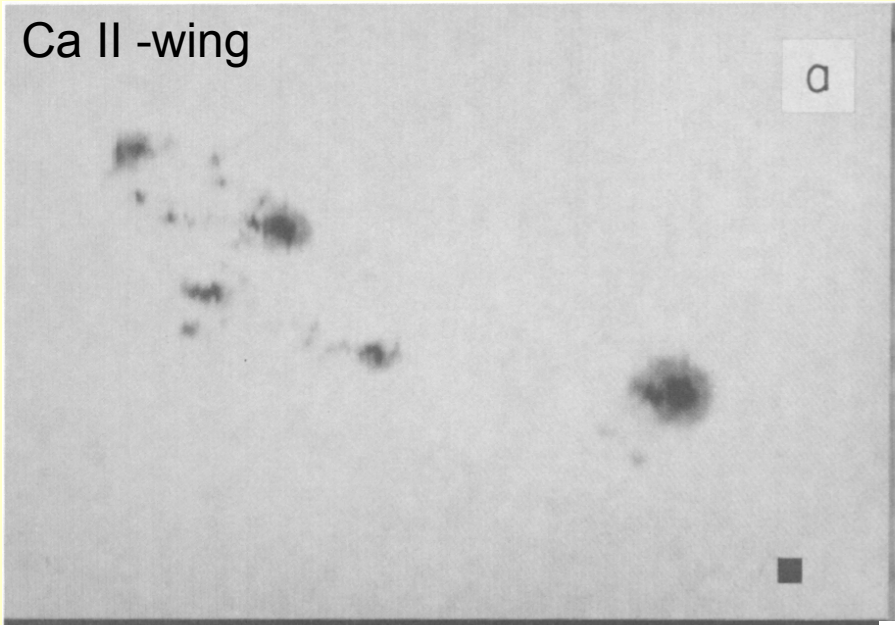

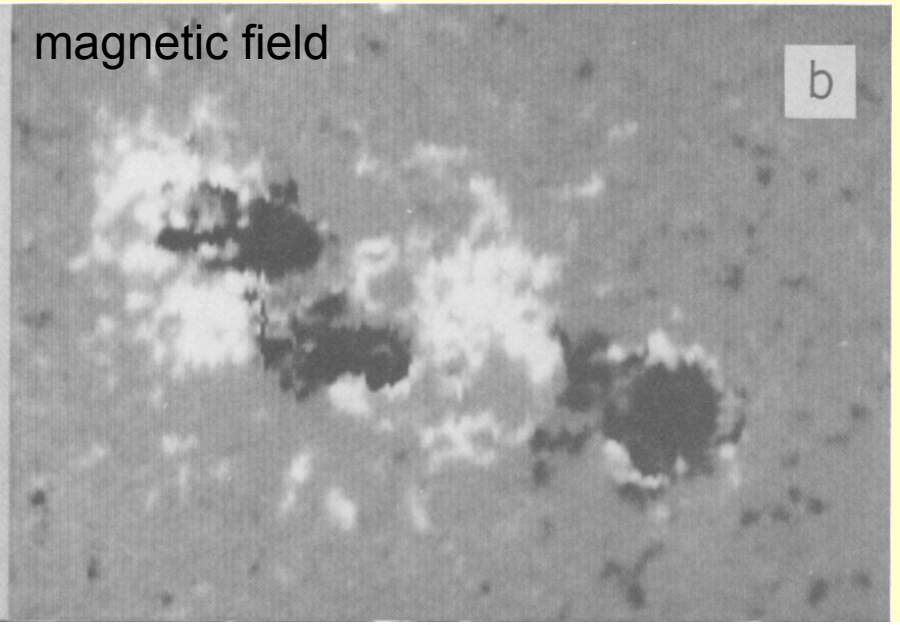

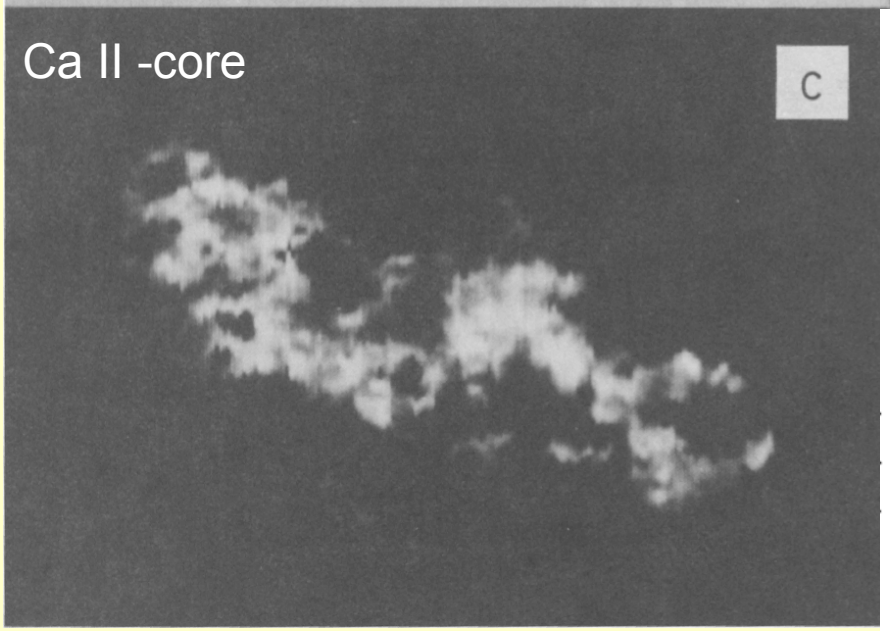

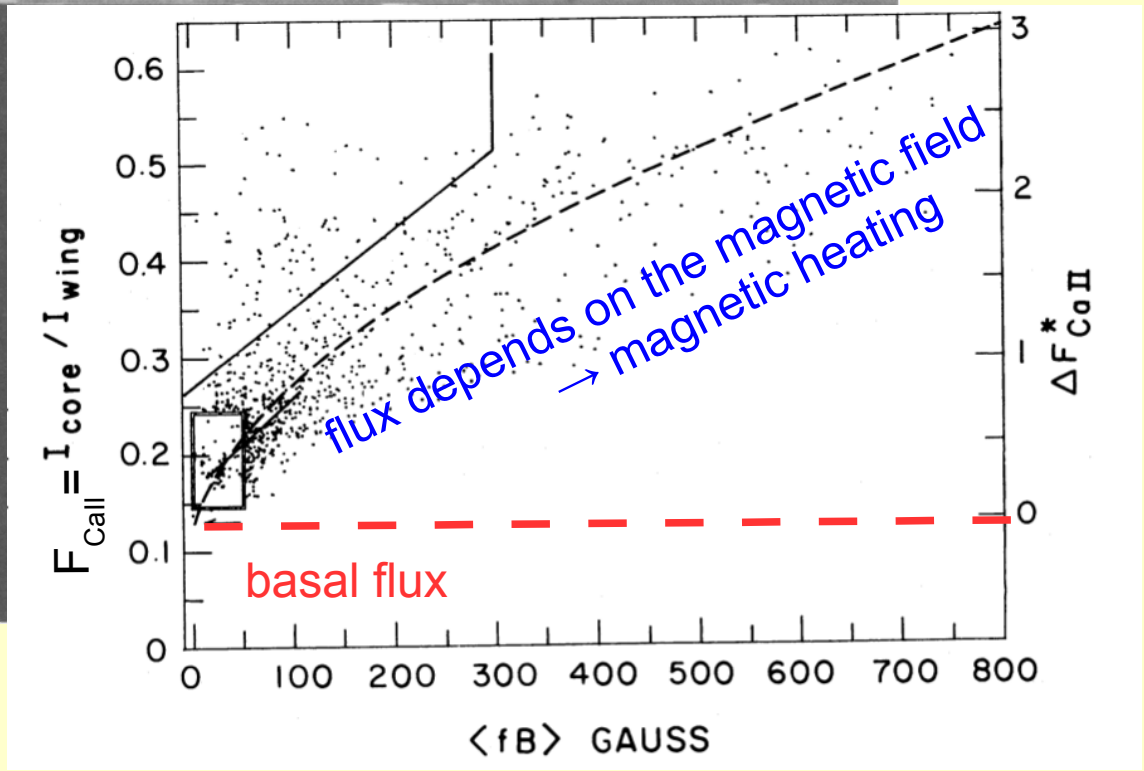

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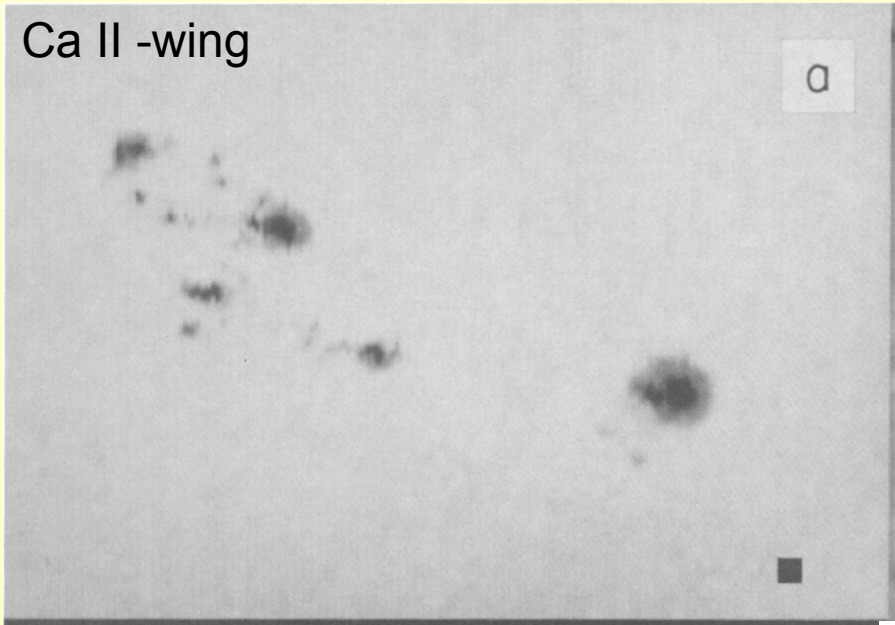

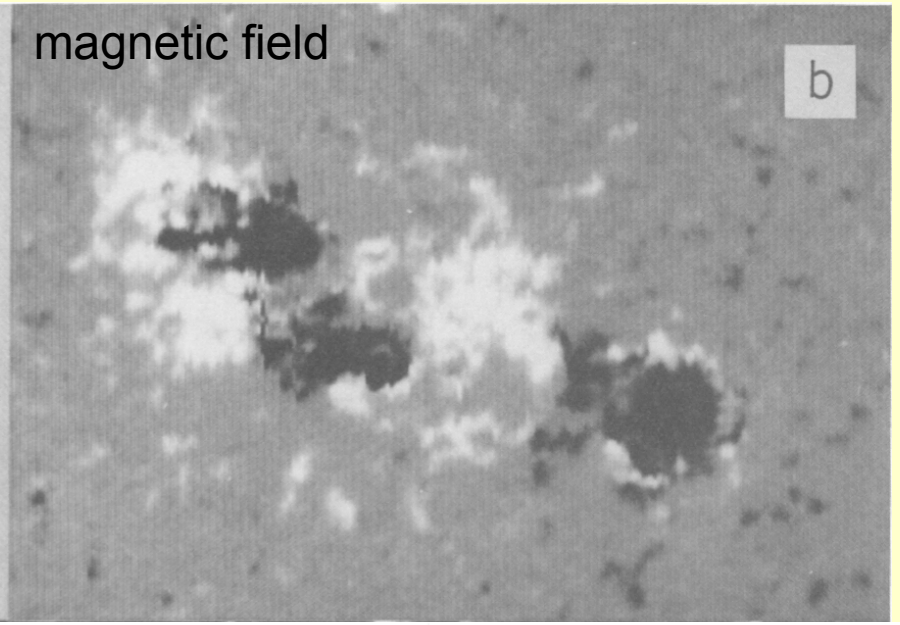

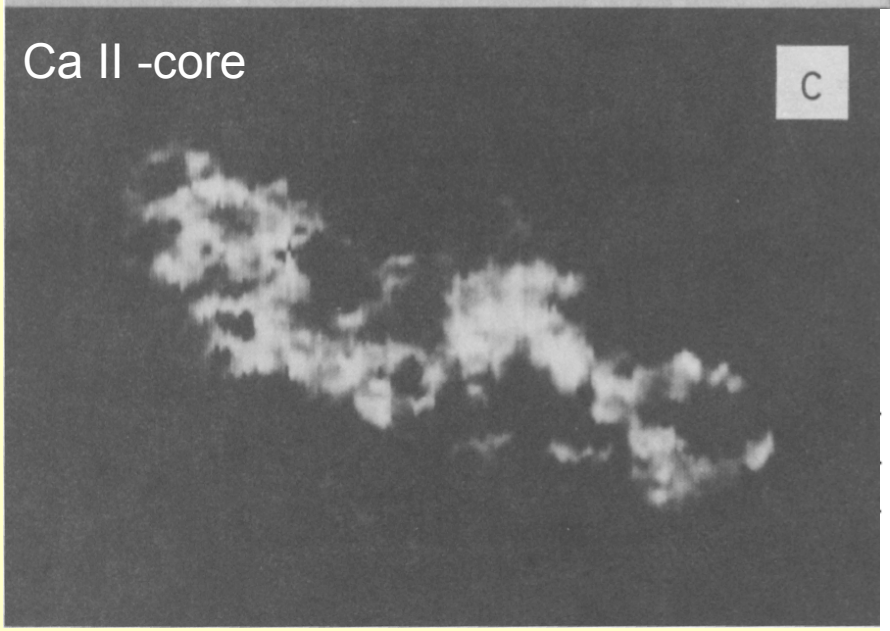

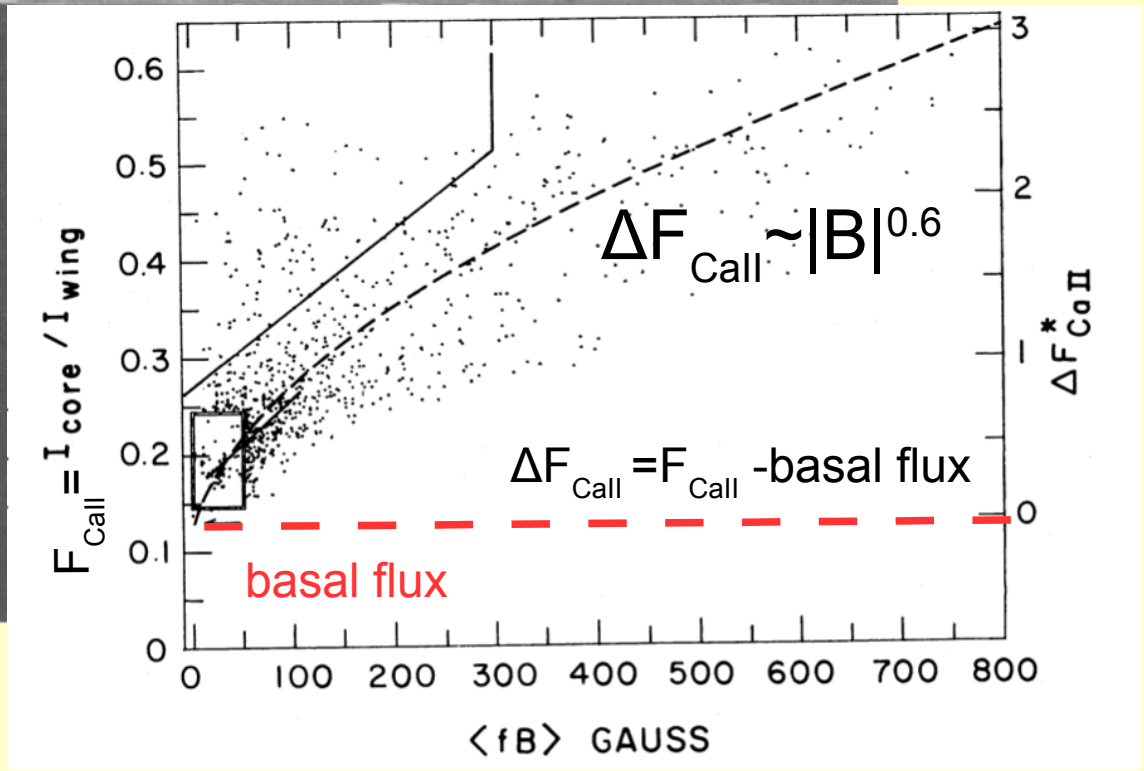

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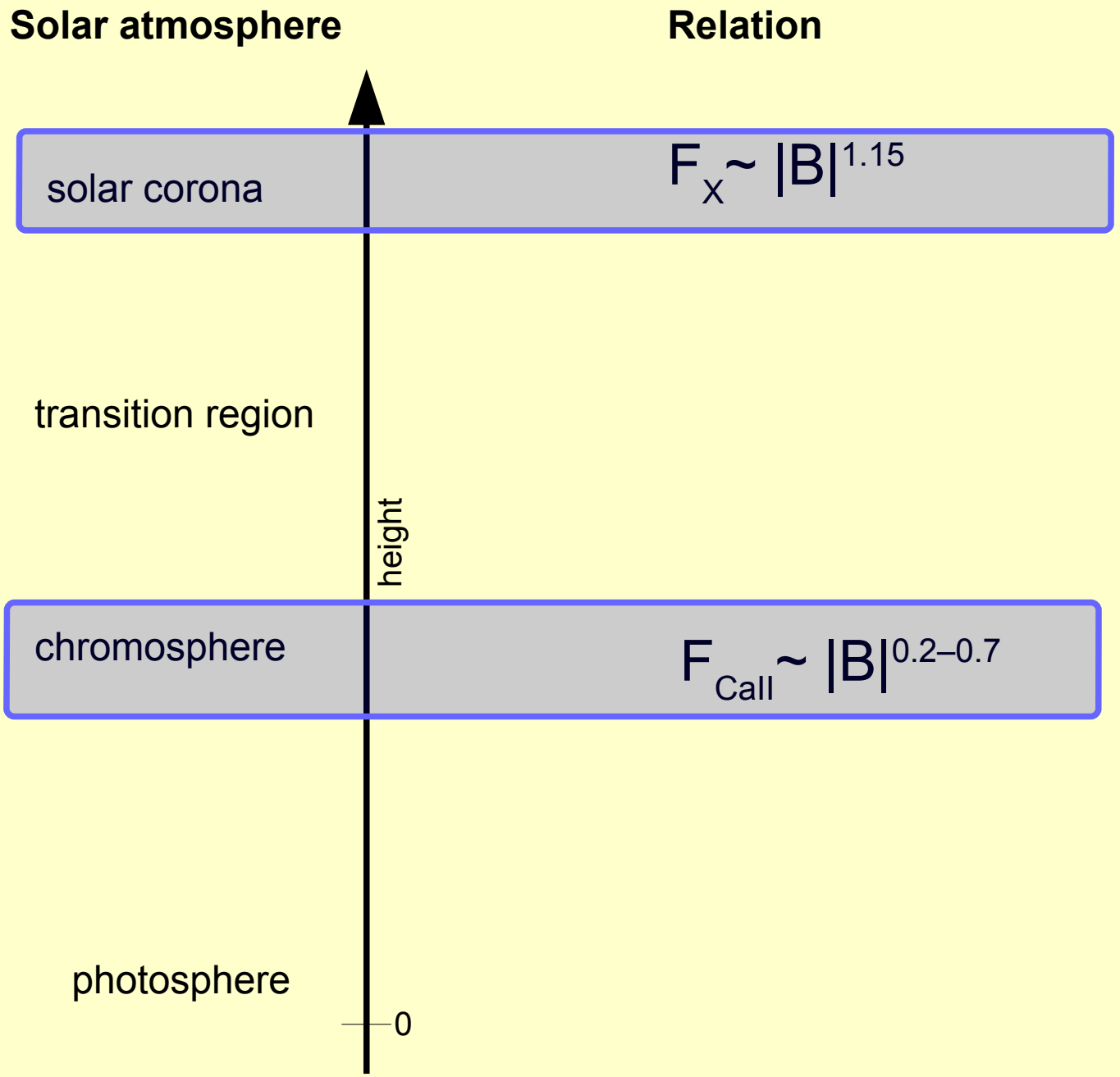


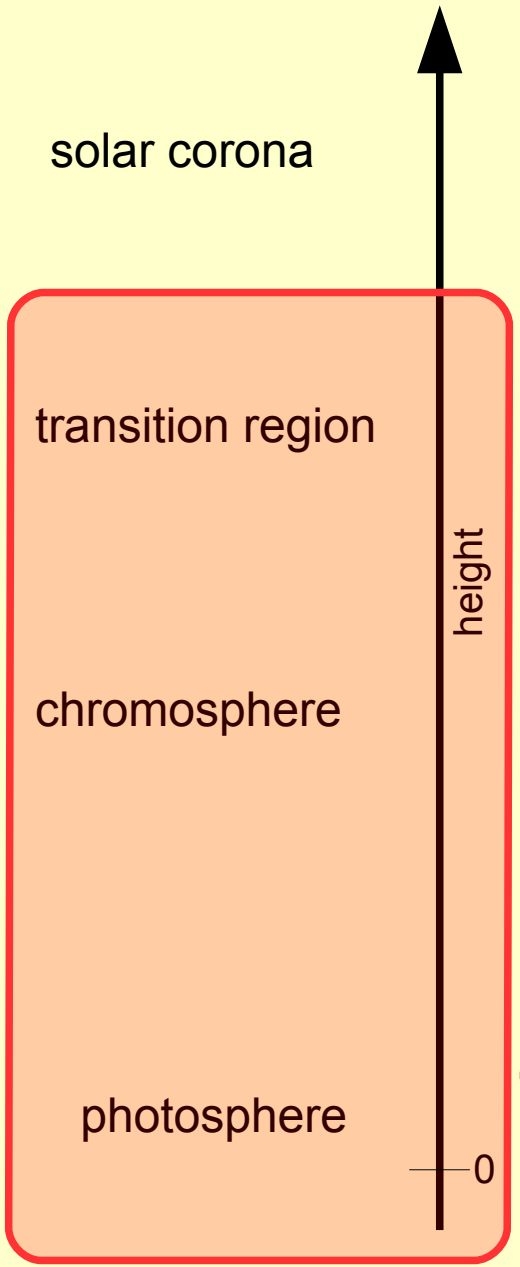
Pevtsov et al. (2003), ApJ 598, 1387

at higher temperatures emission becomes more sensitive to the magnetic field

Schrijver et al. (1989) ApJ 337, 964
Harvey et al. (1999) ApJ 515, 812
Rezai et al. (2007) A&A 466, 1131
Loukitcheva et al. (2009) A&A 497, 273

Magnetic field vs. intensity

Solar atmosphere



Relation

$F_X \sim |B|^{1.15}$

Pevtsov et al. (2003), ApJ 598, 1387

?

at higher temperatures emission becomes more sensitive to the magnetic field

$F_{CaII} \sim |B|^{0.2–0.7}$

Schrijver et al. (1989) ApJ 337, 964
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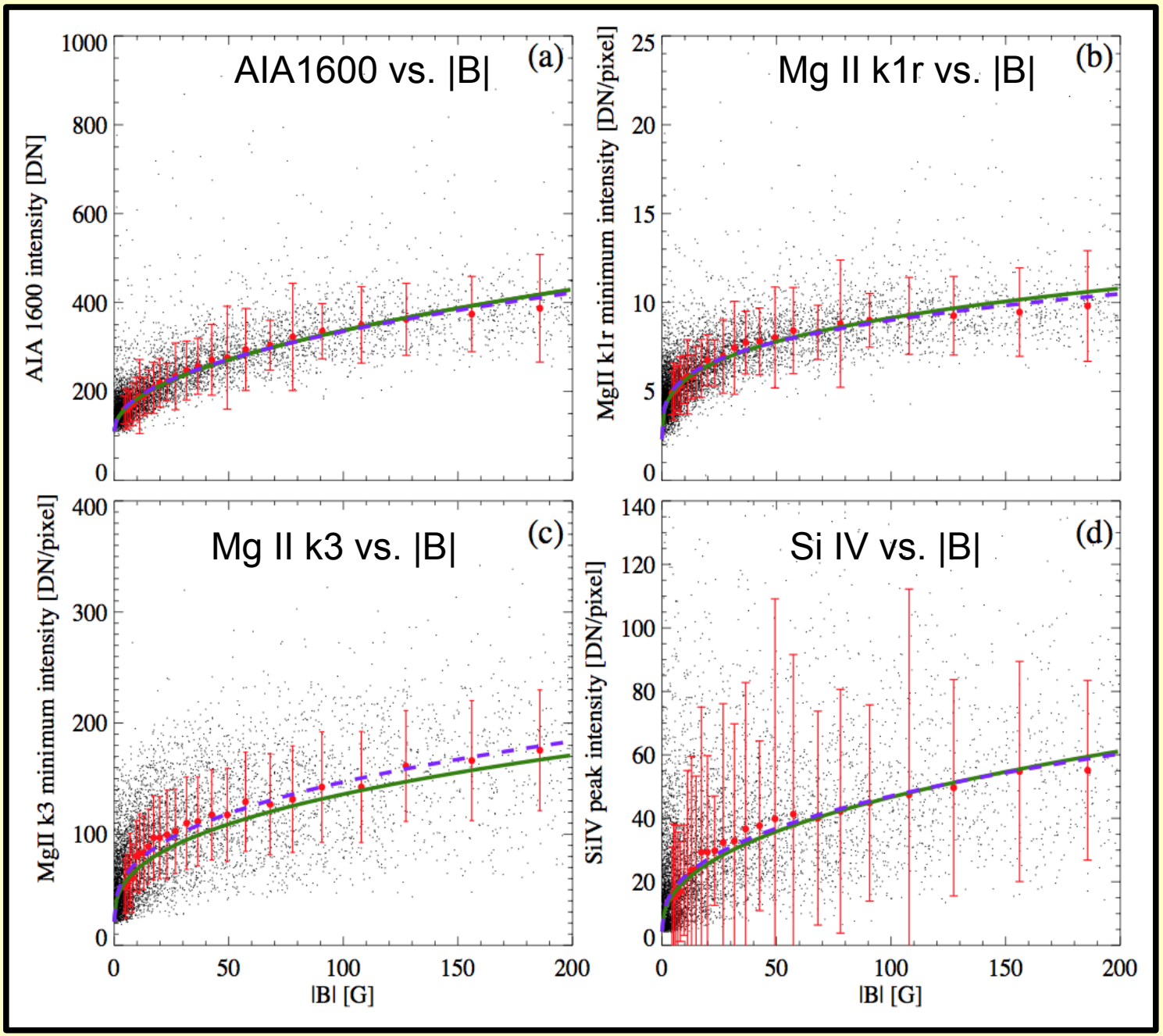
How does the relation of intensity to magnetic field looks like throughout the chromosphere and transition region?

Relation: intensity vs. magnetic field



Barczynski et al. (2017, in prep.)

Analysis:

- basal flux
- correlation
- relation I vs. |B|

  -fitting power law

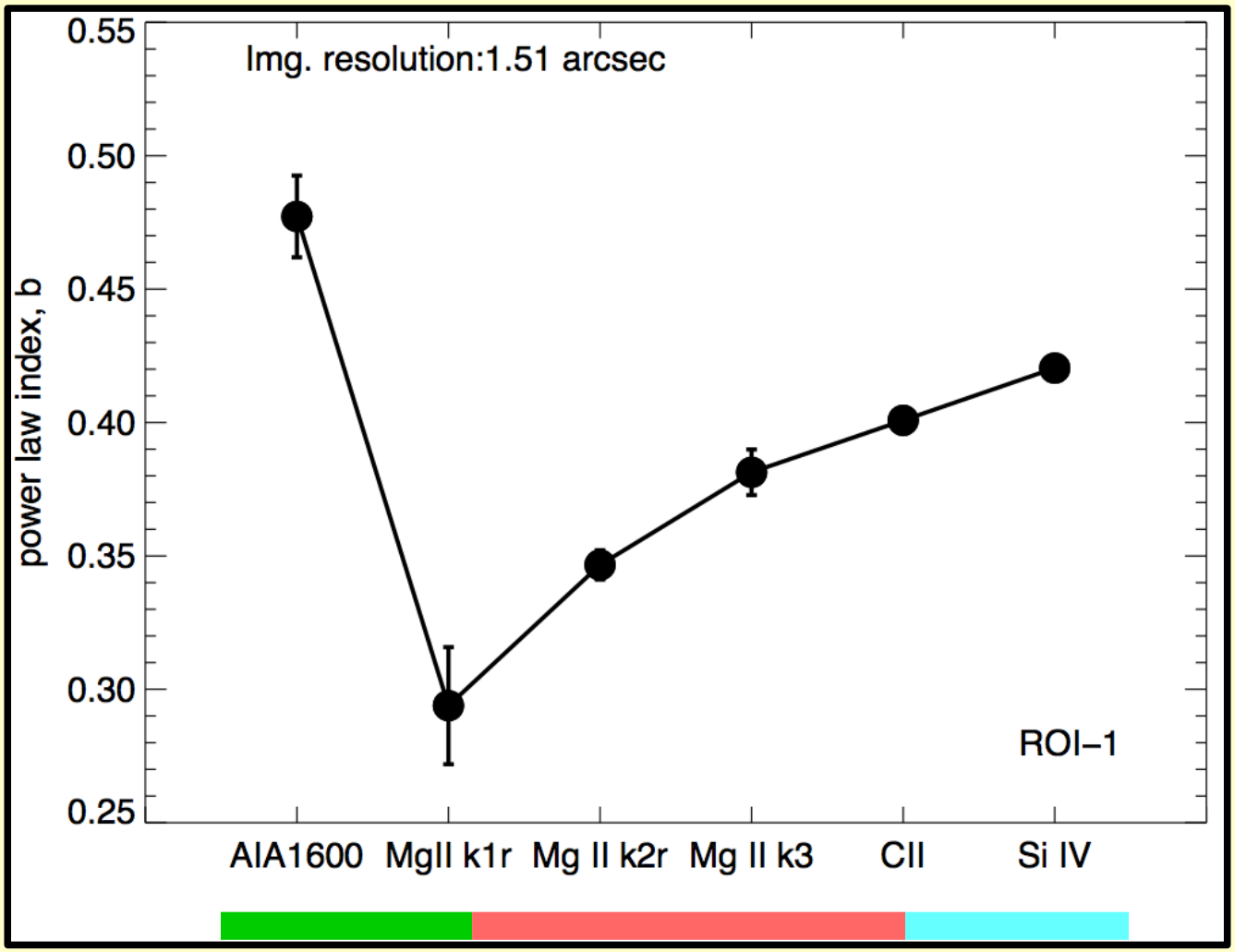
  with offset (basal flux)

power-law index

$$y=ax^b+c$$

basal flux

Relation: intensity vs. magnetic field



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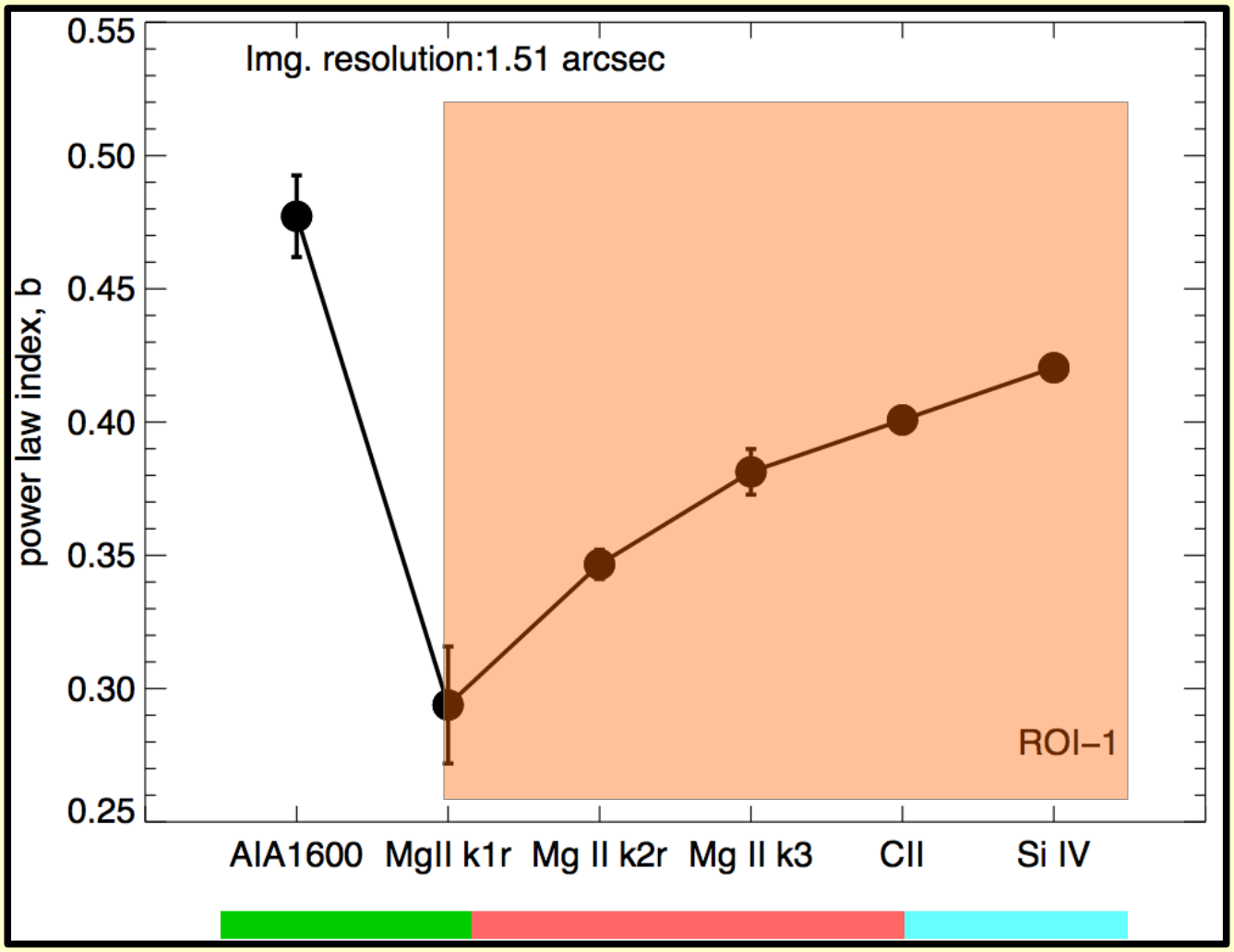
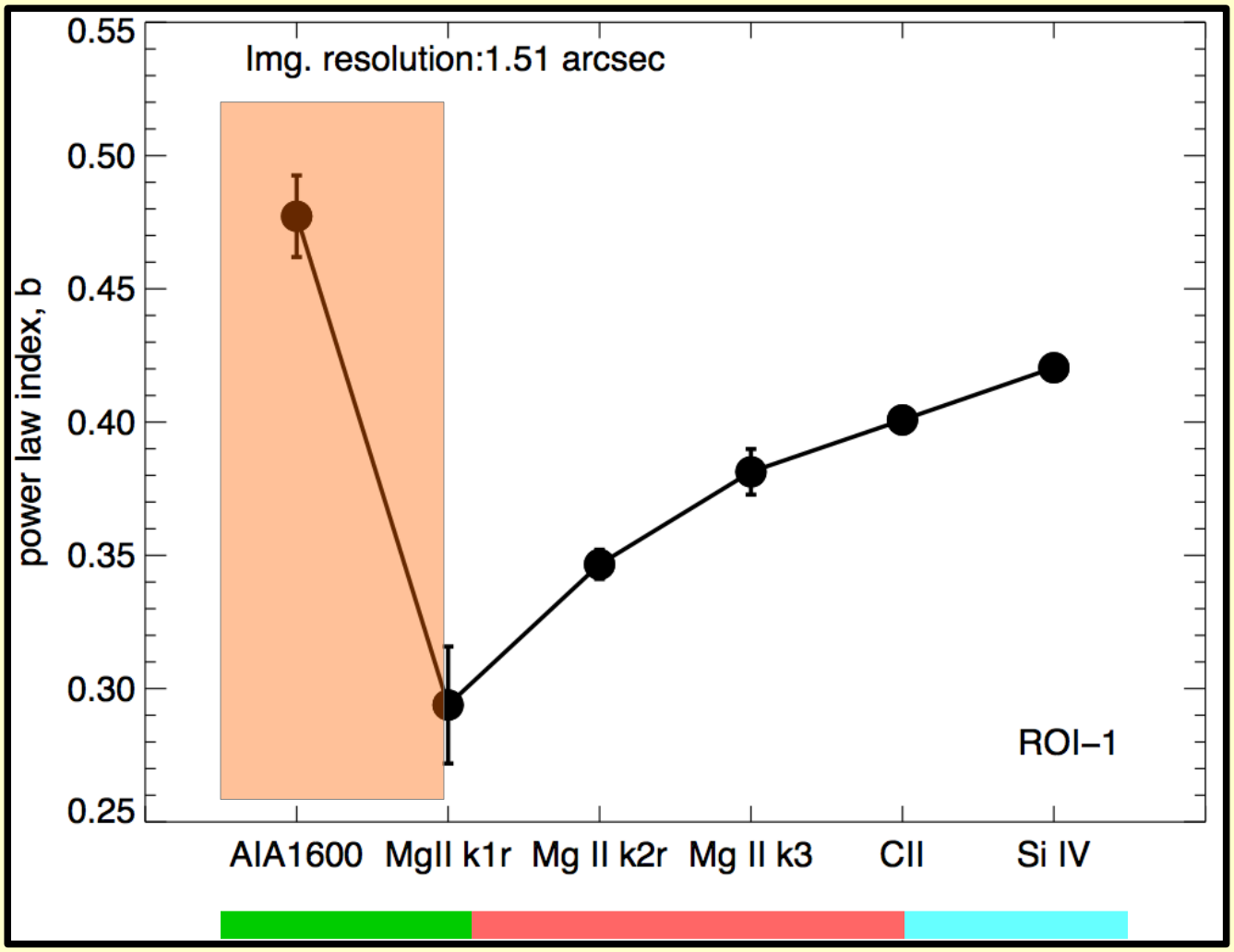


Why power-law index increases with height (Mg II k1-Si IV)?

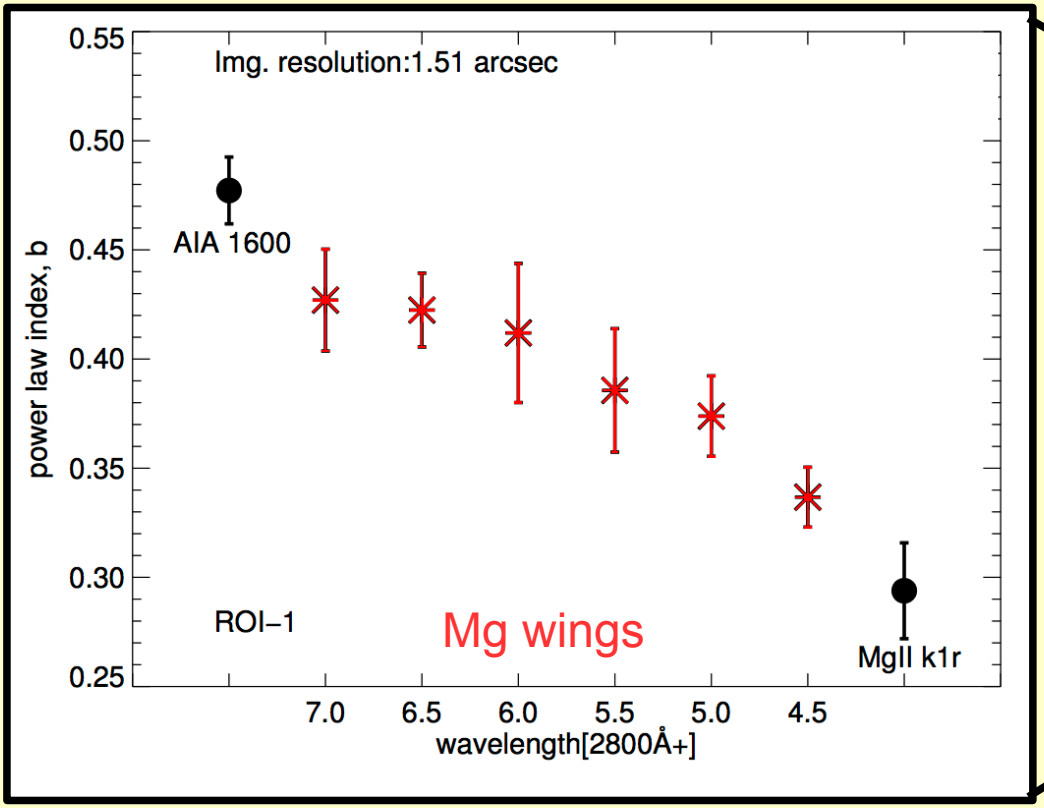
- Increasing sensitivity of the emission to magnetic heating processes

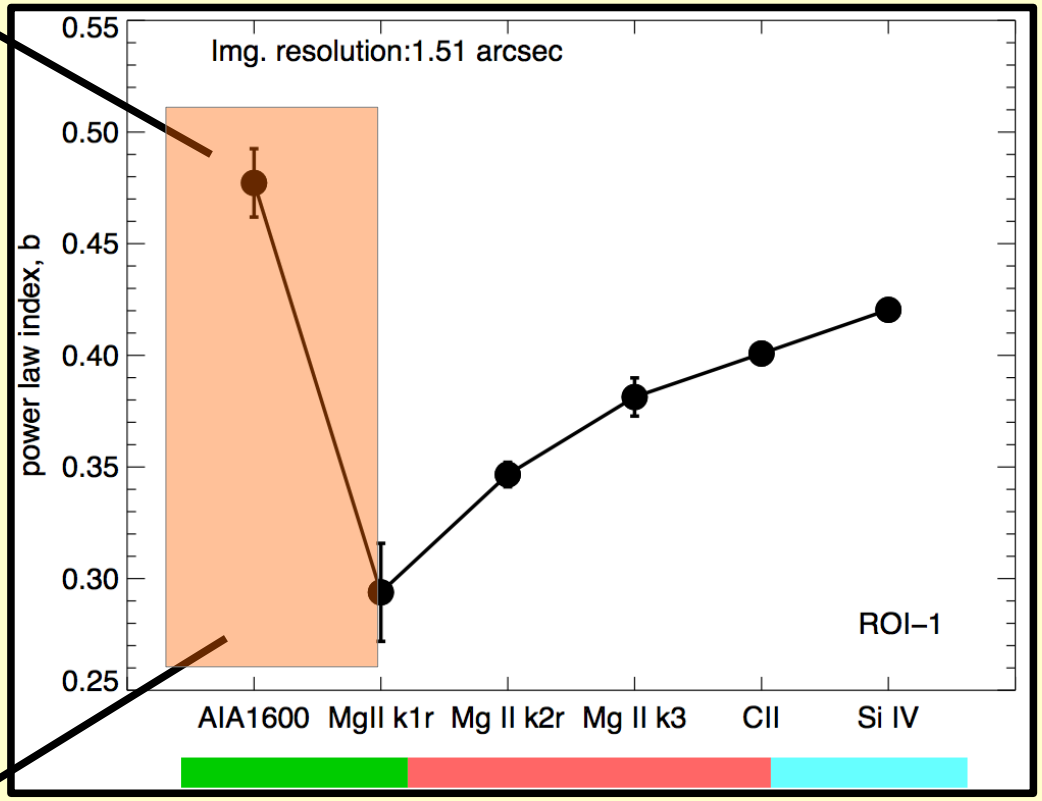
Relation: intensity vs. magnetic field



→ variation in the power-law indices below the temperature minimum has not been reported earlier

Relation: intensity vs. magnetic field





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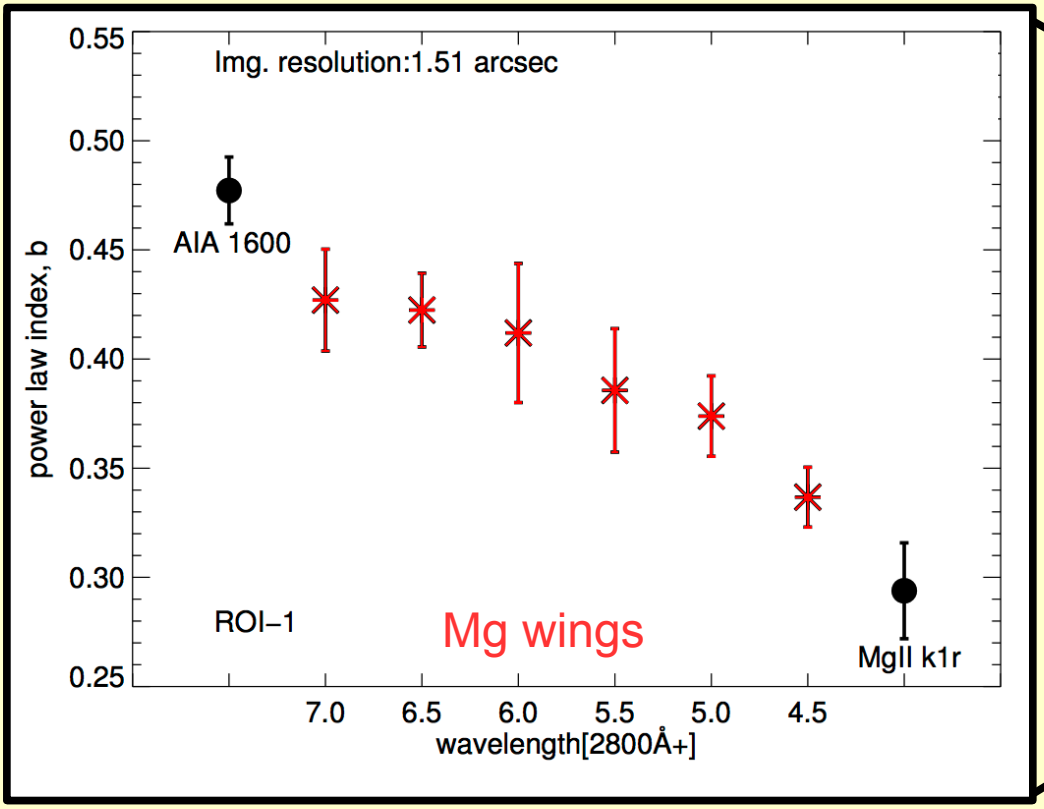
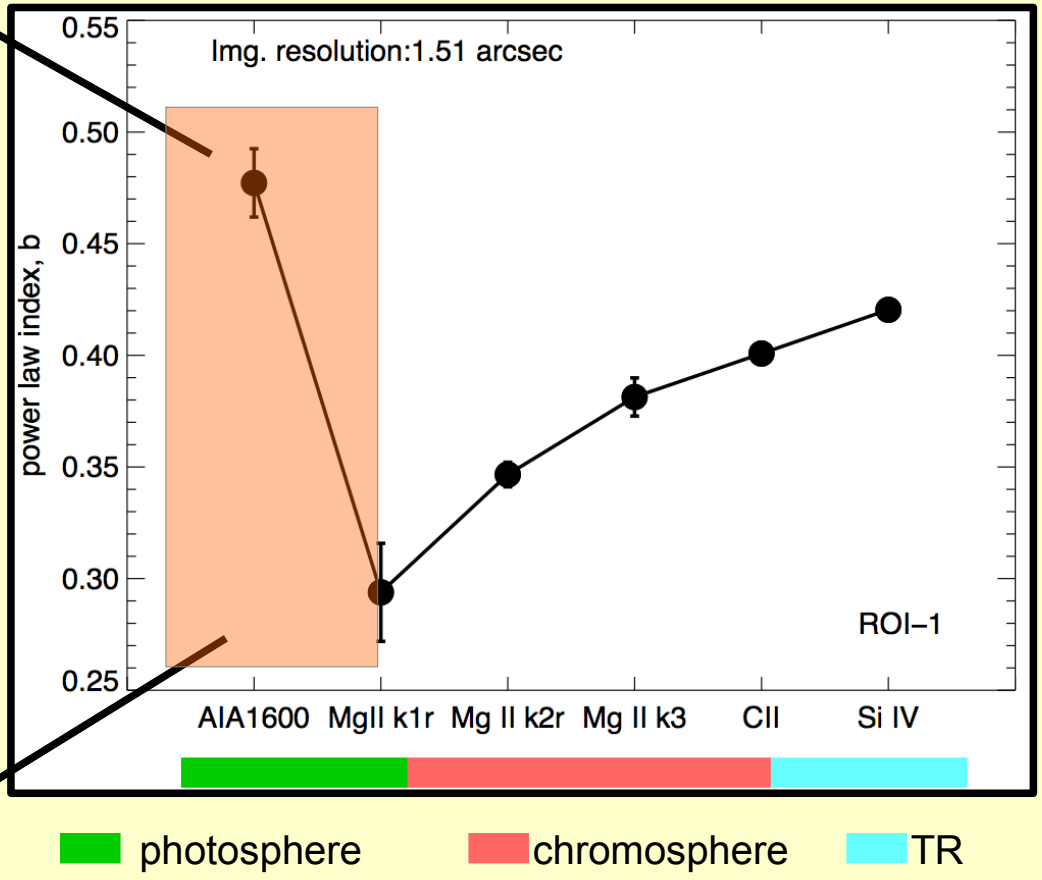
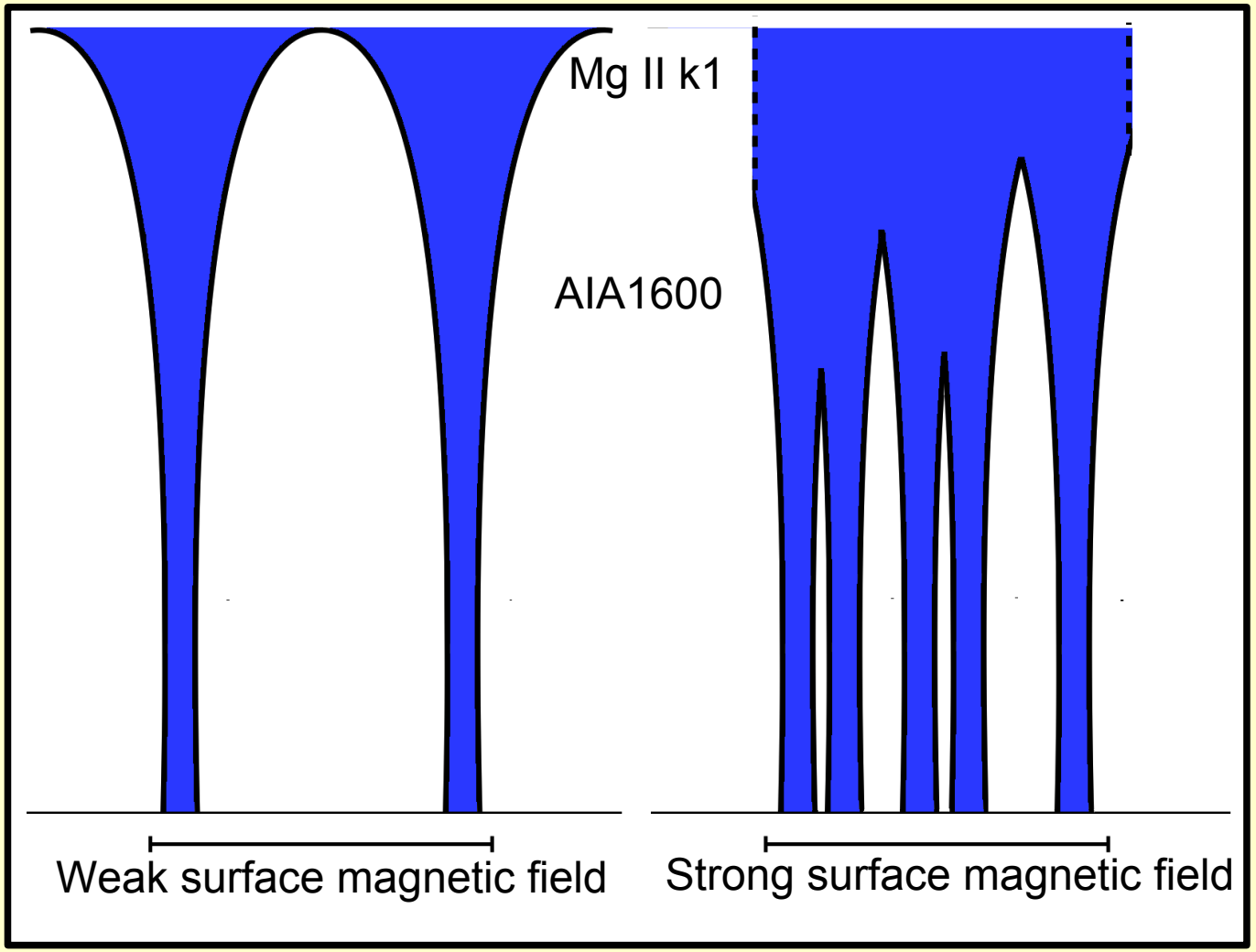




Why power-law index decreases with height (AIA1600-Mg II k1) ?

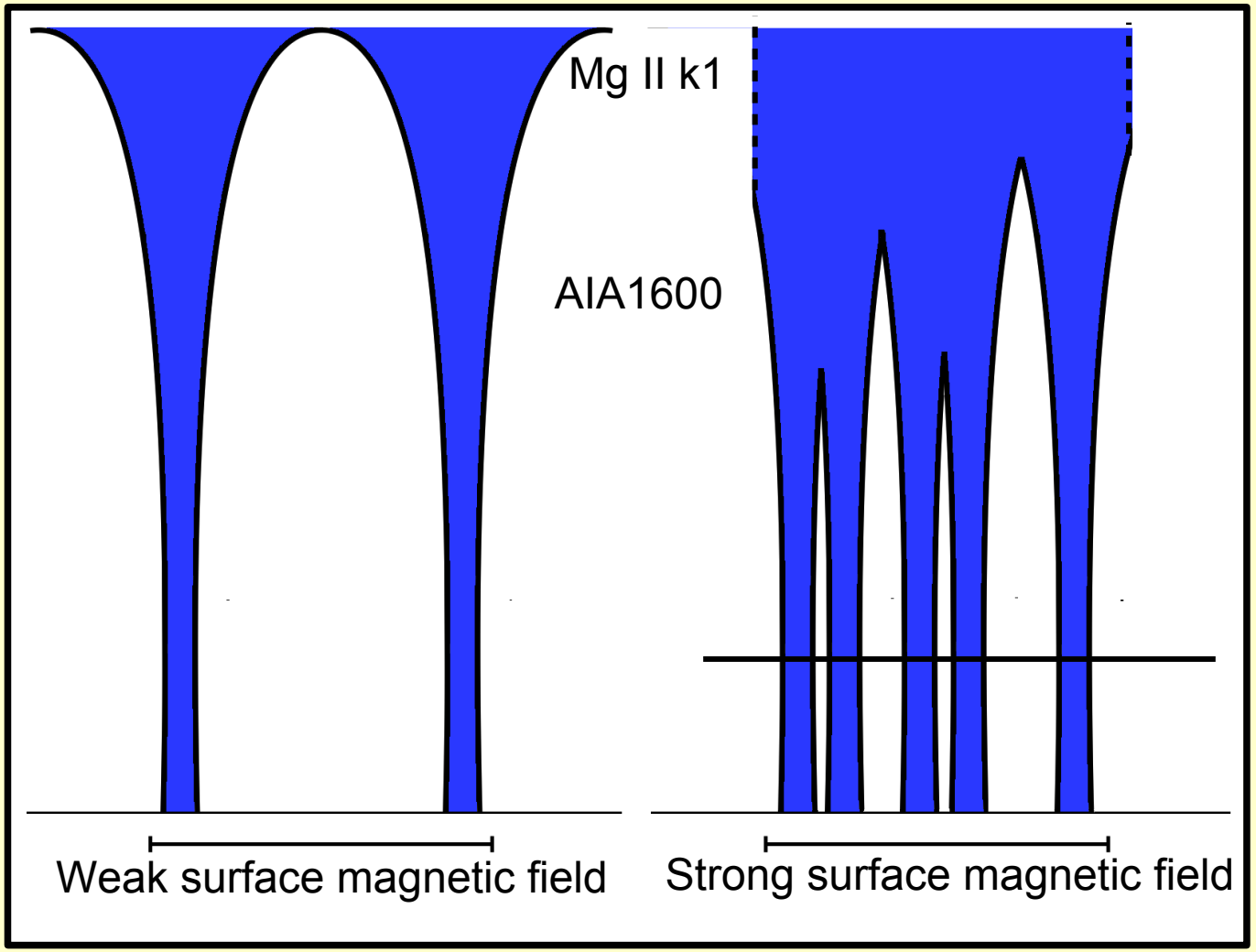
- wavelength dependent visibility (or contrast) of magnetic flux tubes in the UV (e.g. in 1600 Å and Mg II k1r)
- Schrijver et. al (1989) suggest the geometrical explanation through flux tube expansion is responsible for the non-linear relation

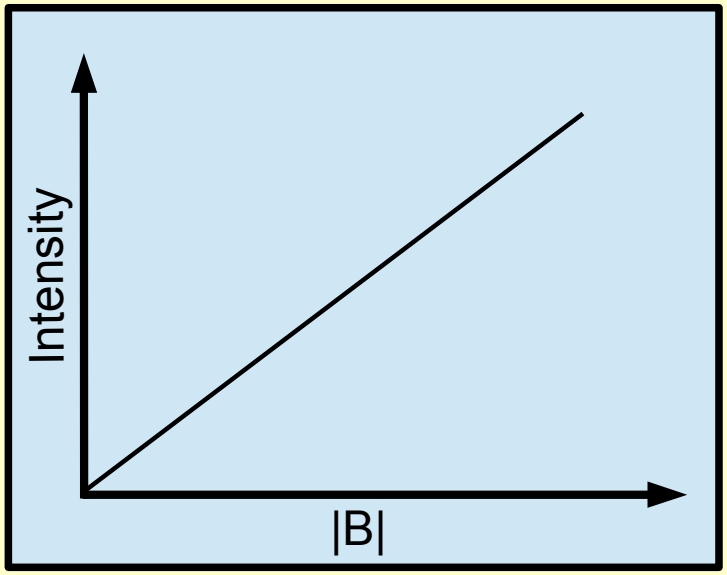
Flux-tube expansion



- Packing more flux tube to the same area
  → flux tube merge at lower height

Flux-tube expansion





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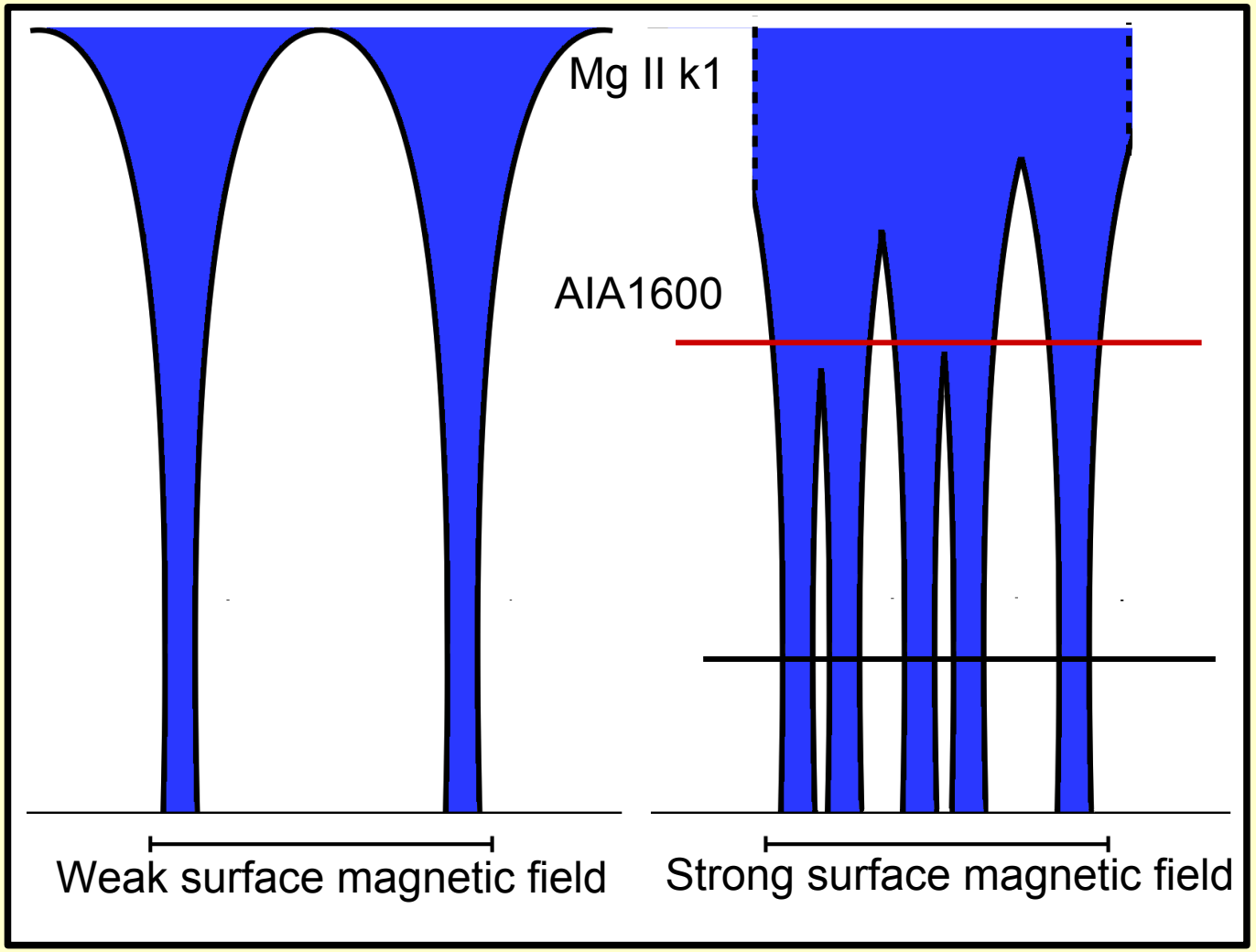

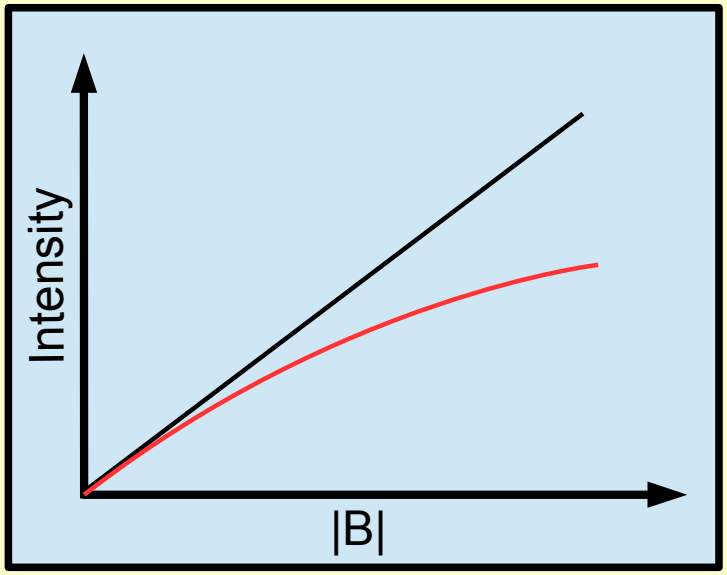

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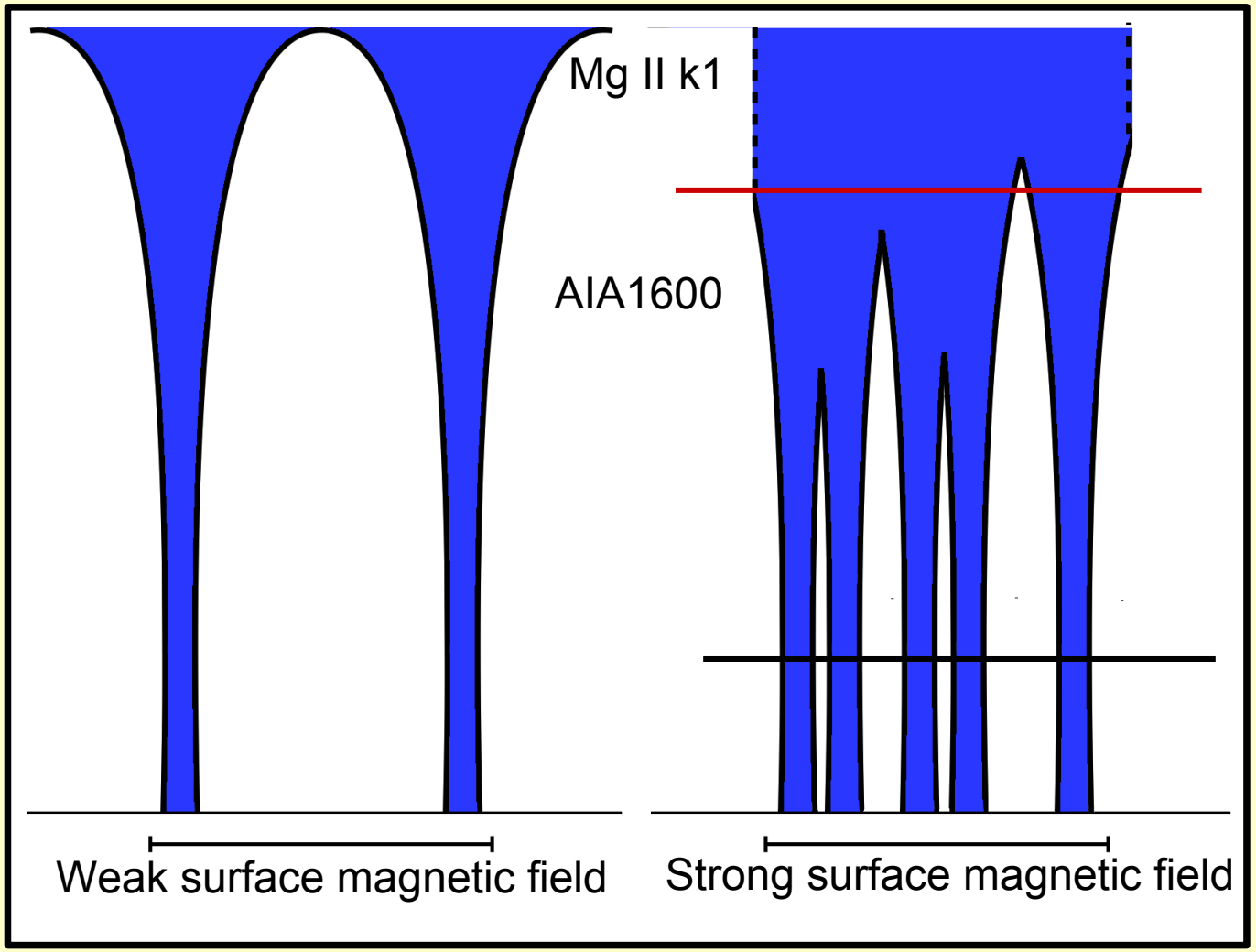

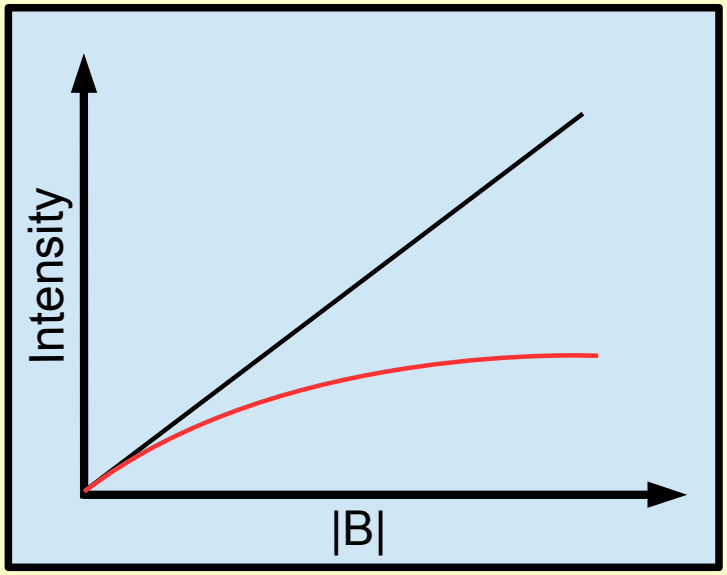

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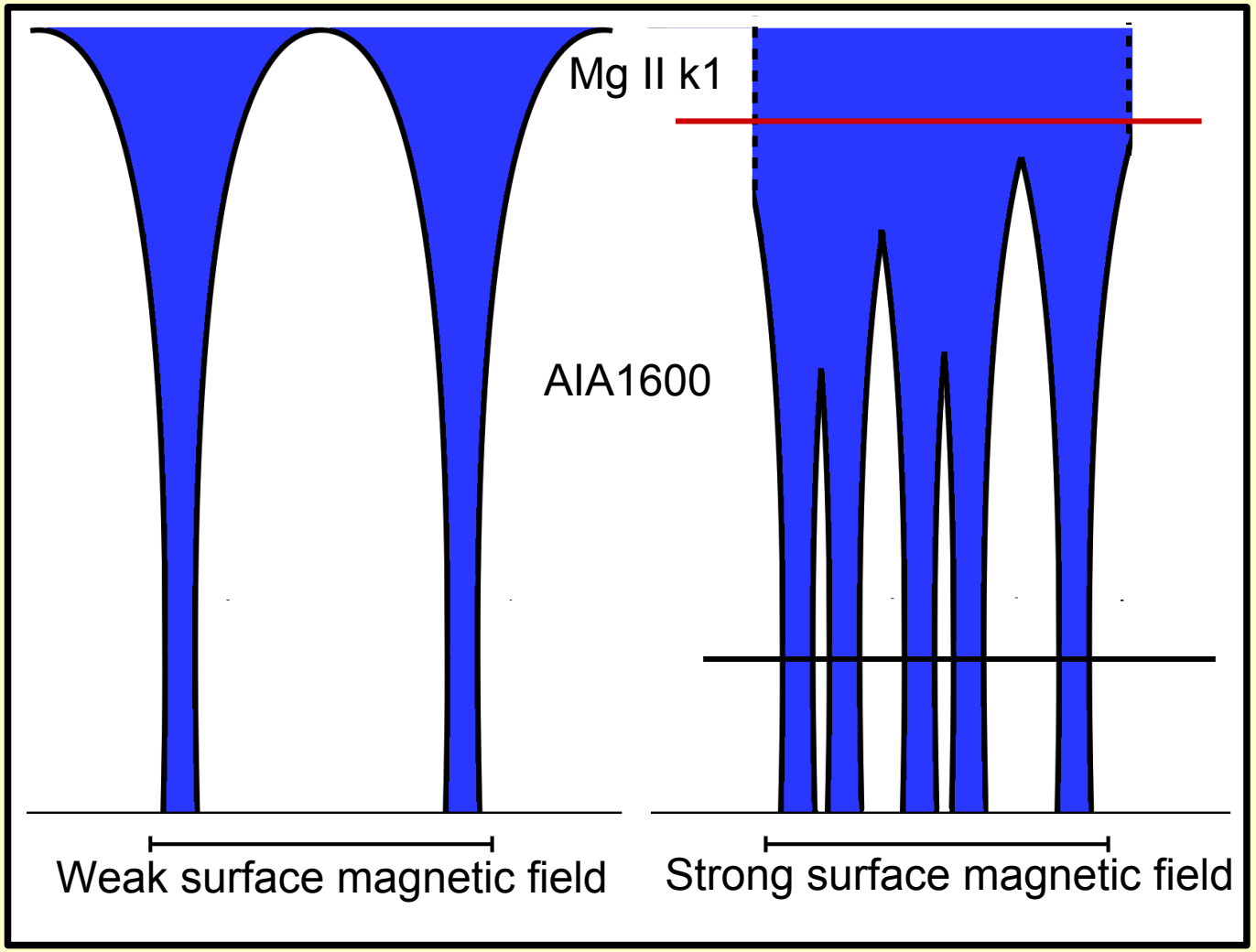

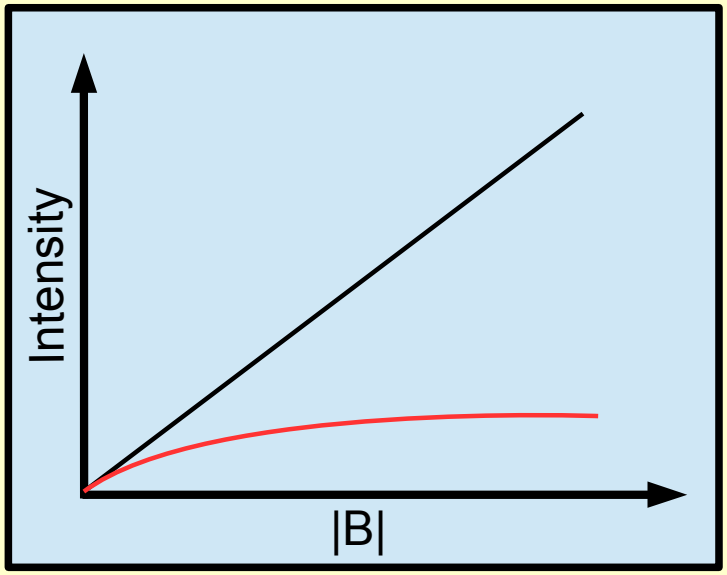

- Packing more flux tube to the same area
  → flux tube merge at lower height

- Moving up between the upper photosphere to temp. minimum
  → higher power-law-index

Conclusions

- The small hot loops exist in the solar atmosphere

  Such unresolved structures show power-law relations between intensities and magnetic field

- The power law index decreases from deeper layers to T_{min}
  →flux tube geometrical expansion effect
  → wavelength dependent visibility effect (Rouppe van der Voort et al. 2016, ….)

- The power law index increases with temperature above T_{min}
  →increasing sensitivity of the emission to magnetic heating processes

Thank you for your attention!

barczynski@mps.mpg.de