Toward Improved Understanding of Magnetic Fields Participating in Solar Flares

Maria D. Kazachenko (CU Boulder),
Benjamin Lynch, Brian T. Welsch, Antonia Savcheva

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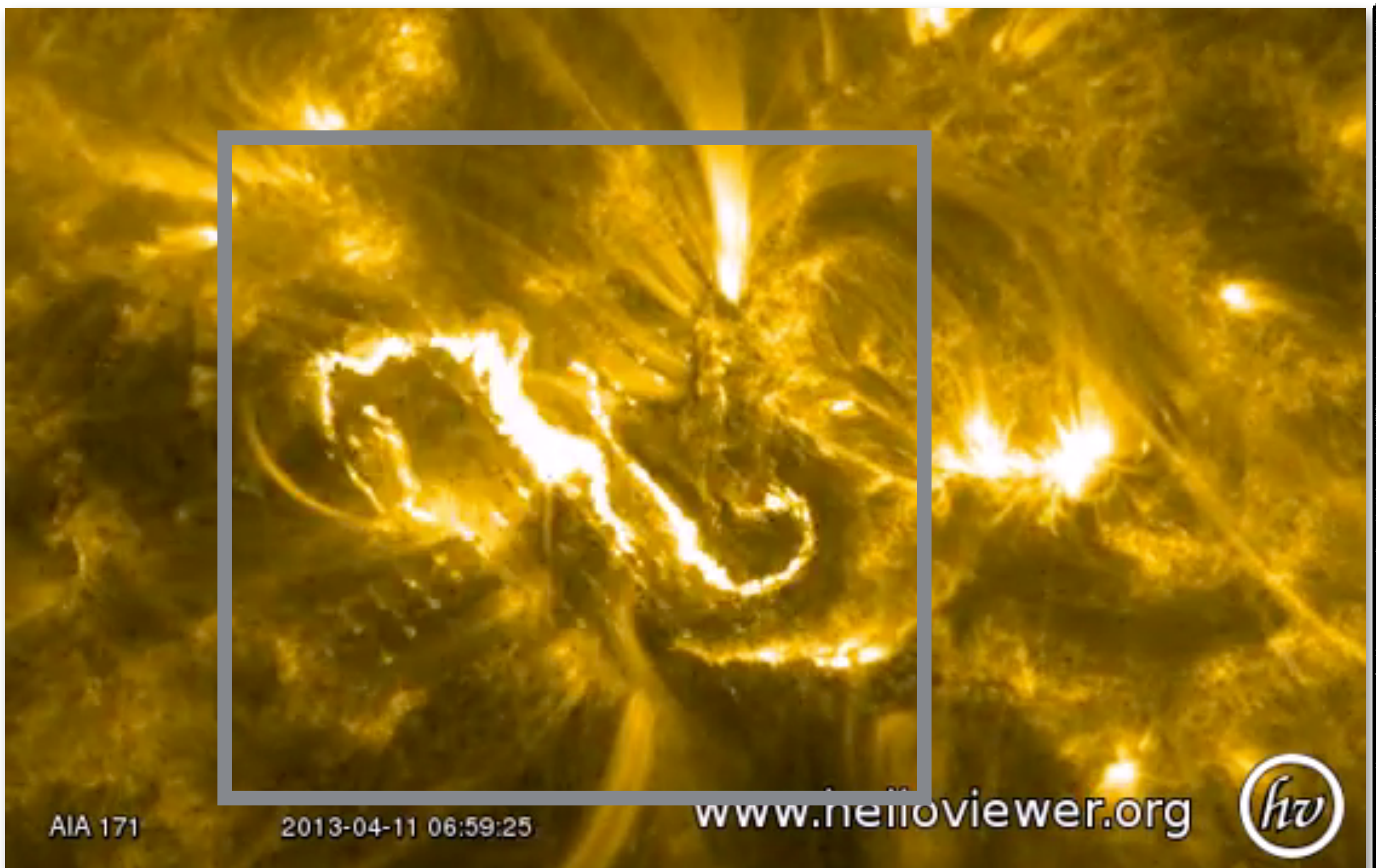
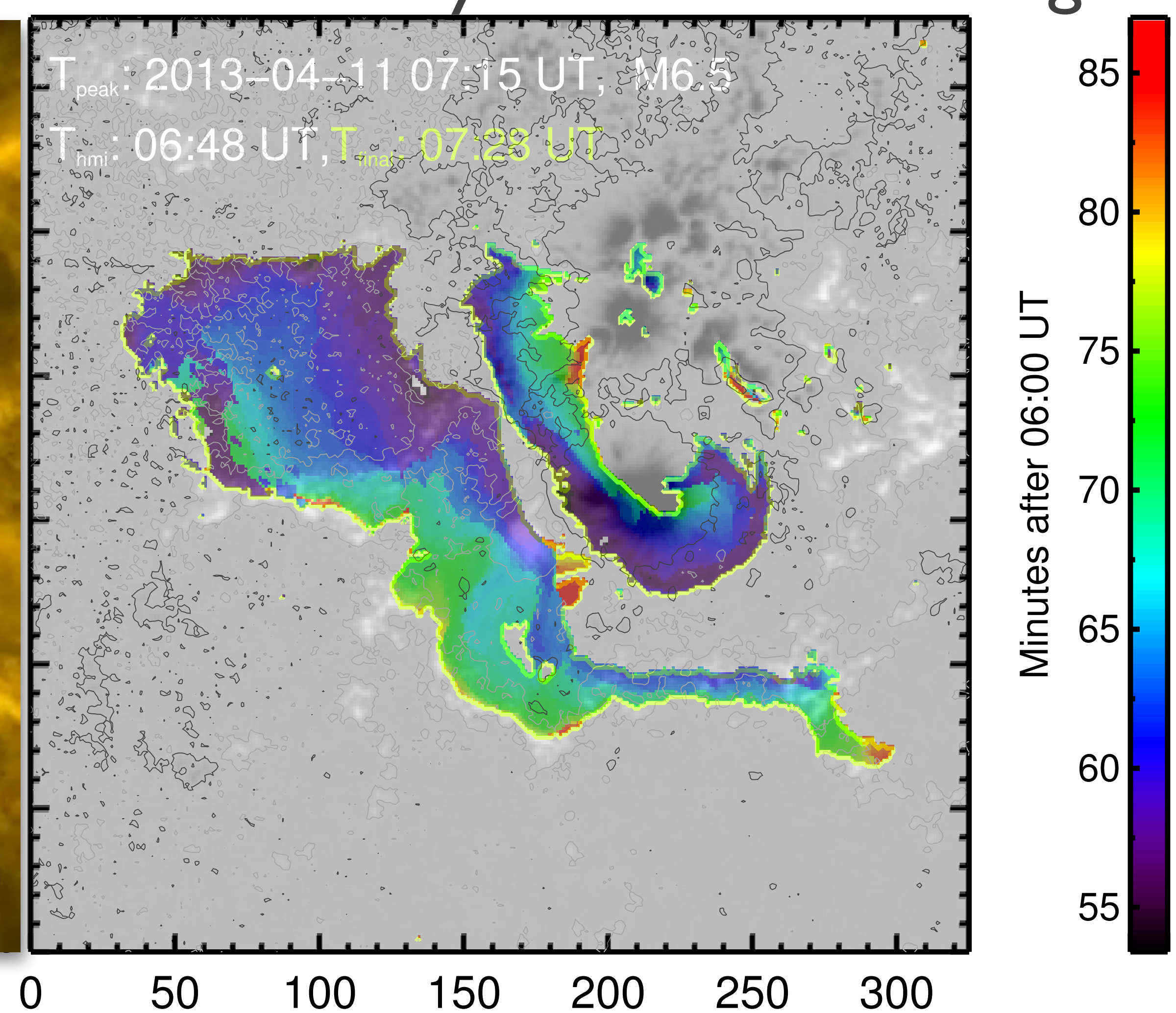
How Do Photospheric Magnetic Fields Participating in the Flare Differ From Non-Flaring Magnetic Fields?

Flare ribbons, shown below, are the chromospheric footpoints of reconnected field lines

Plotting areas swept by ribbons on top of photospheric magnetic fields, we can identify flare-reconnecting B



M6.5 flare, AIA/SDO 171



Time evolution of ribbons over Br

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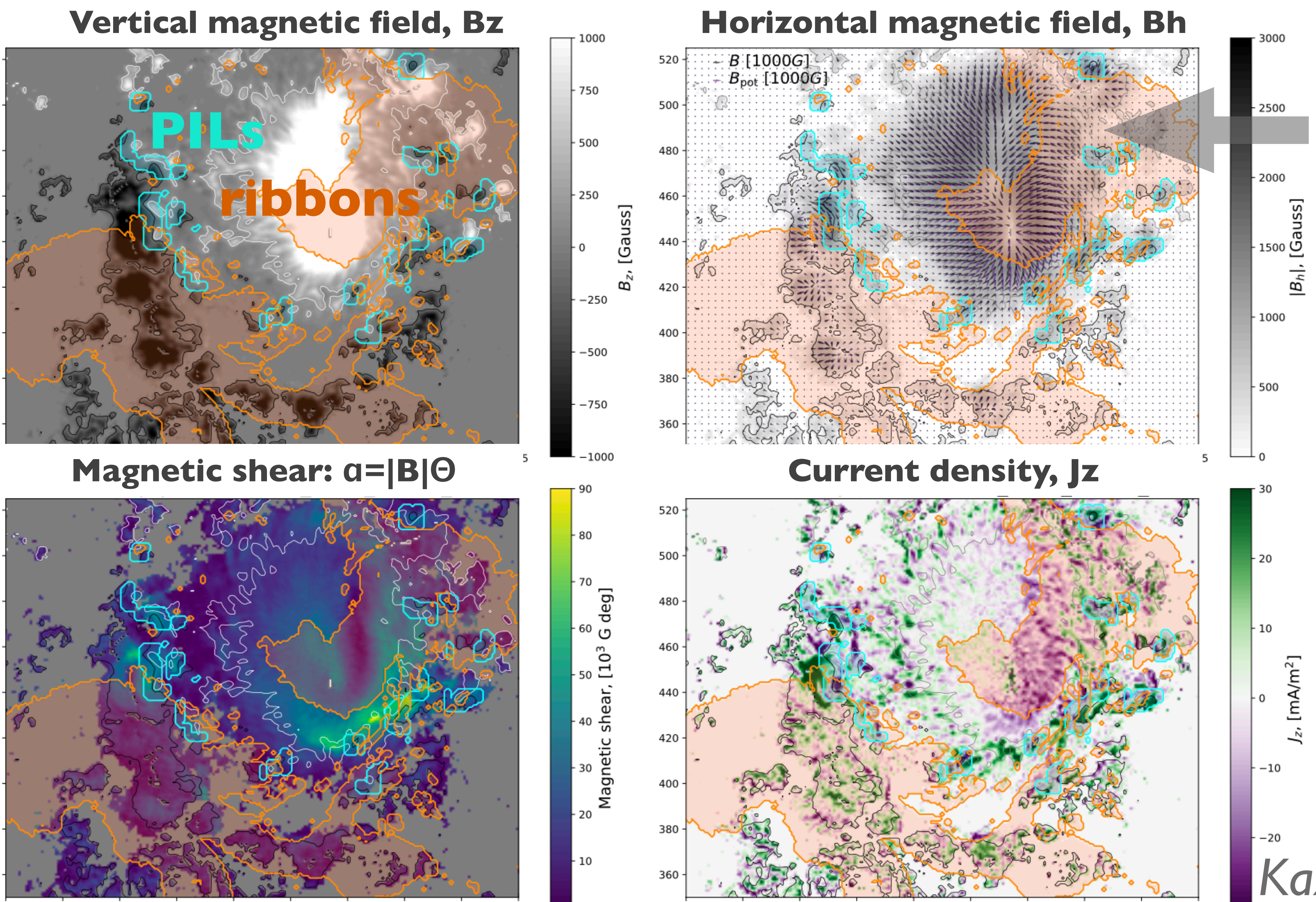
Methods / Data

Main idea: analyze properties of **B** within ribbon, ARs and PILs.

Data: vector **B** and ribbon images from SDO.

We use these data to find magnetic flux, shear, current density, net current.



Example of **B**-properties in an AR before an X1.6 flare

We analyze 40 flares (10 X-, 28 M- and 2 C-class) to create a new dataset:

FlareMagDB

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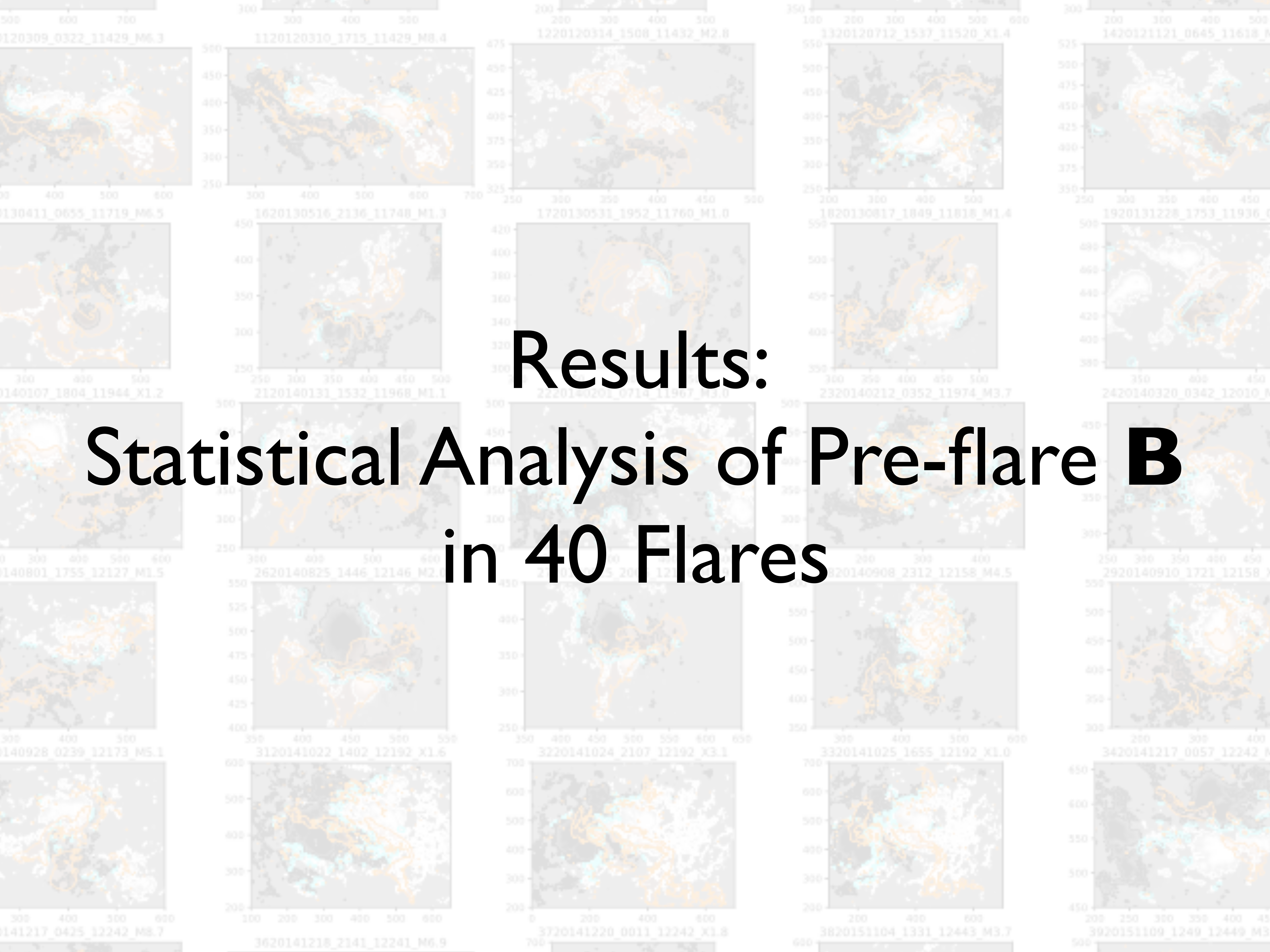


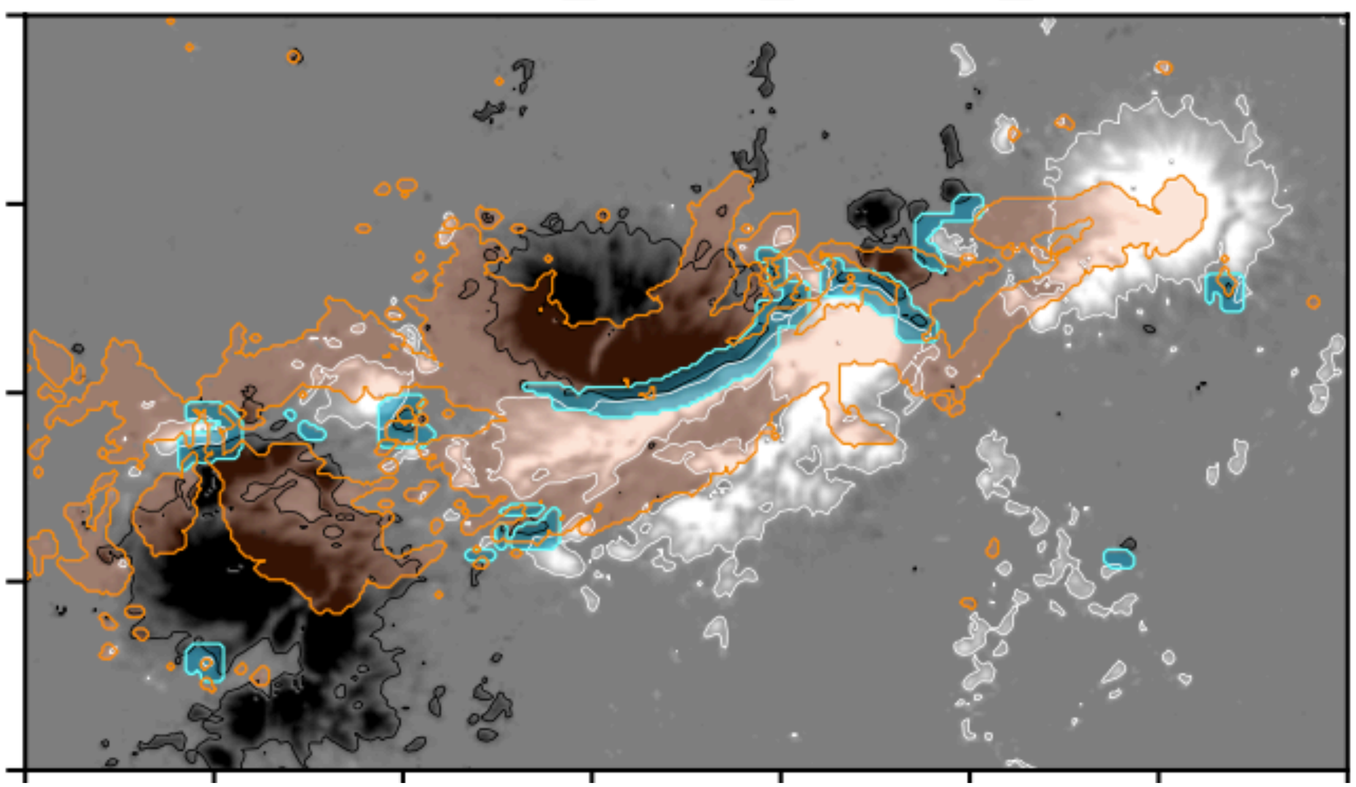
Results:
Statistical Analysis of Pre-flare **B** in 40 Flares

PIL vs. Ribbon Morphology

We find that PIL regions and ribbons have different morphology

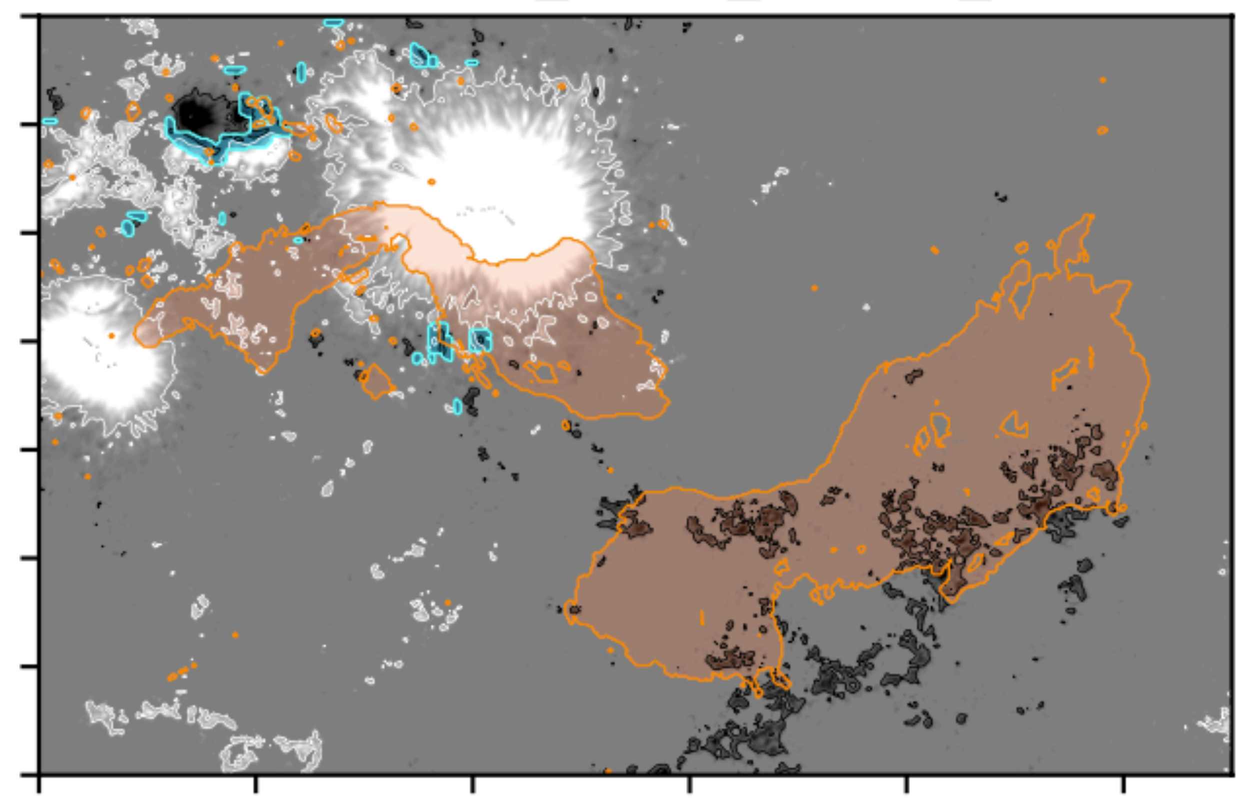
Below is an event where PILs <u>overlap</u> with ribbons

120110215_0144_11158_X2.2



Here is another event where PILs <u>do not overlap</u> with ribbons

2020140107_1804_11944_X1.2



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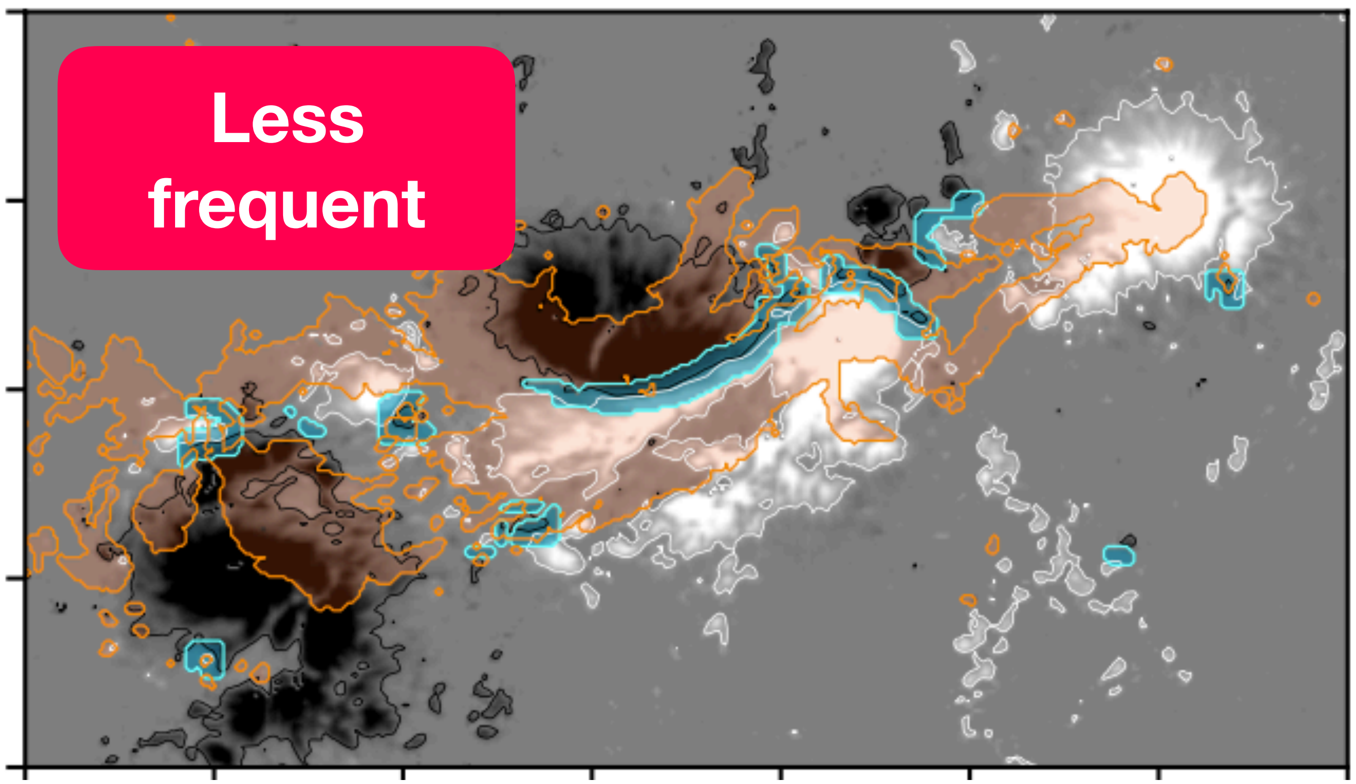

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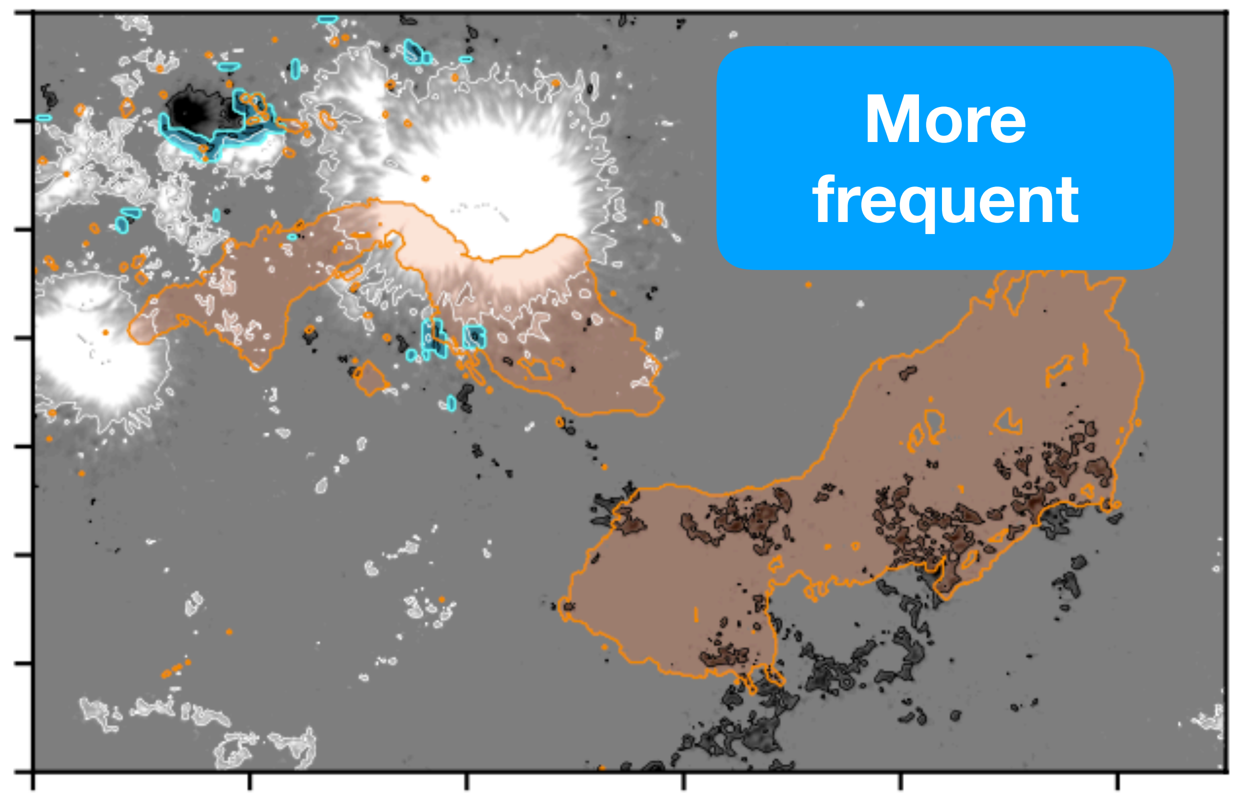

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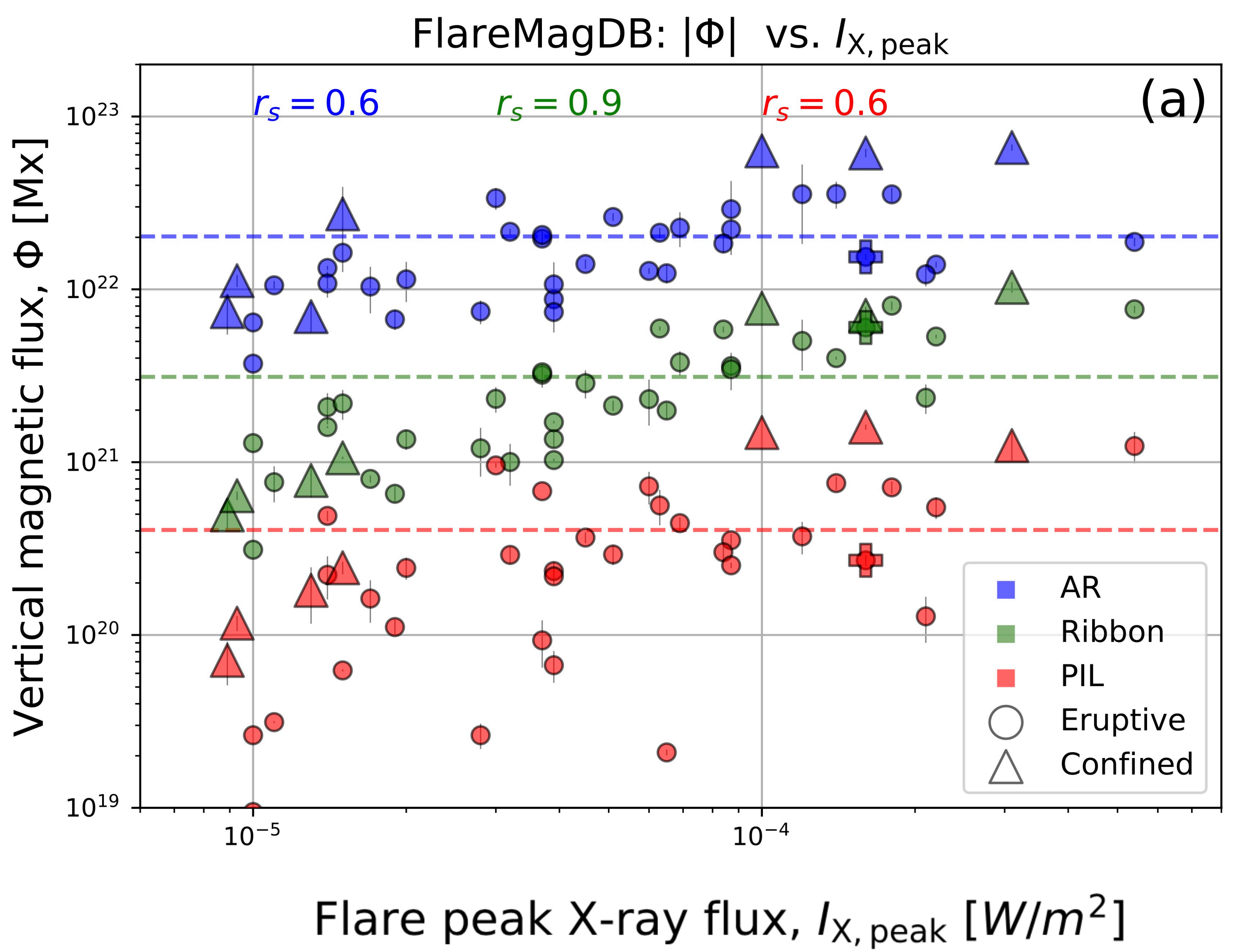
Magnetic Fluxes

<u>On the right</u>: AR, ribbon and PIL magnetic fluxes vs. flare peak X-ray flux

We find:

1. Larger flares have larger PIL and rec. fluxes.
2. Confined flares (▲) have larger PIL fluxes



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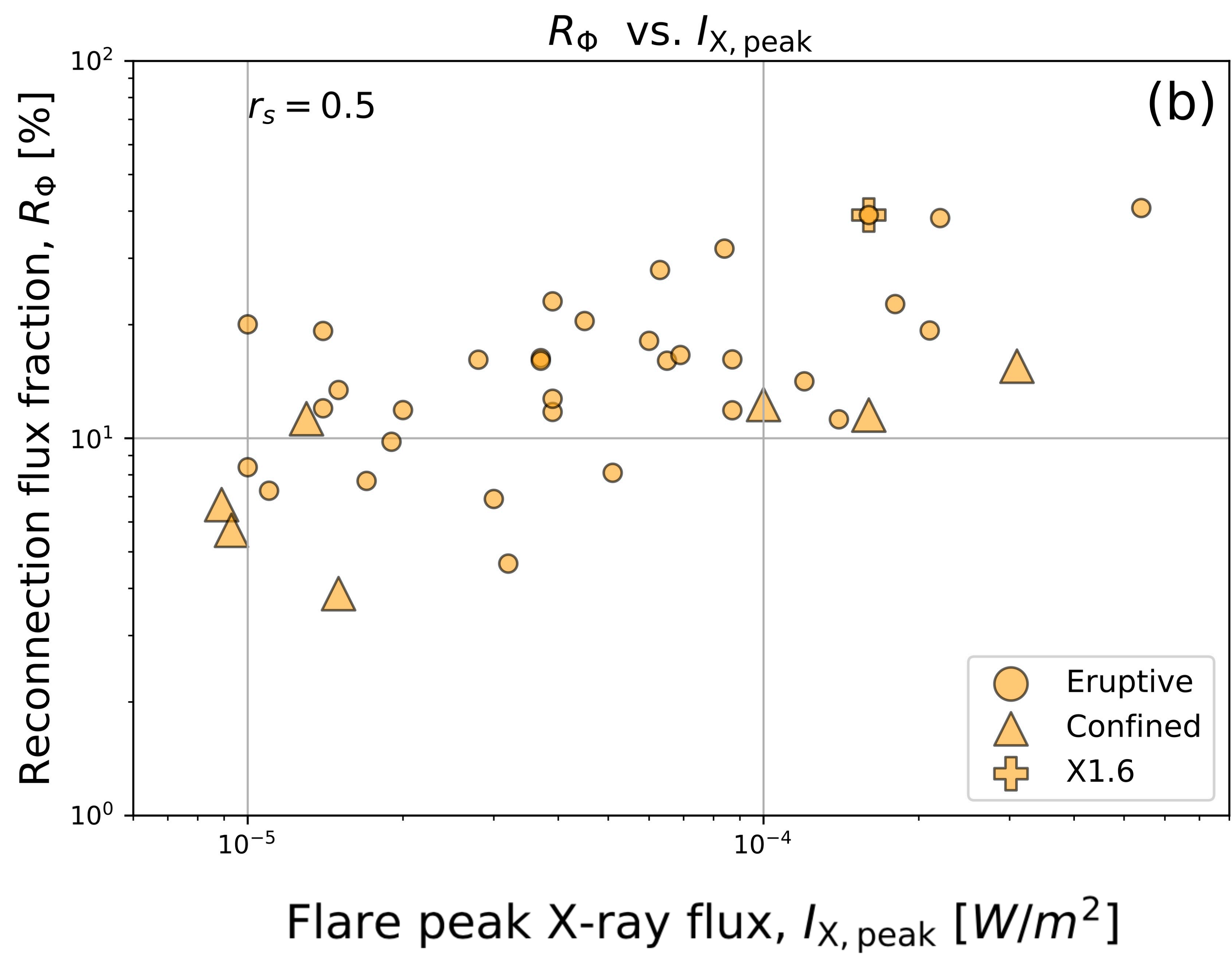
Reconnection Flux Fraction

<u>On the right</u>: reconnection flux fraction vs. flare peak X-ray flux:

We find:

- Moderate correlation between the flare peak X-ray flux and the fraction of AR magnetic flux participating in the flare
- Confined events (▲) have lower R_Φ



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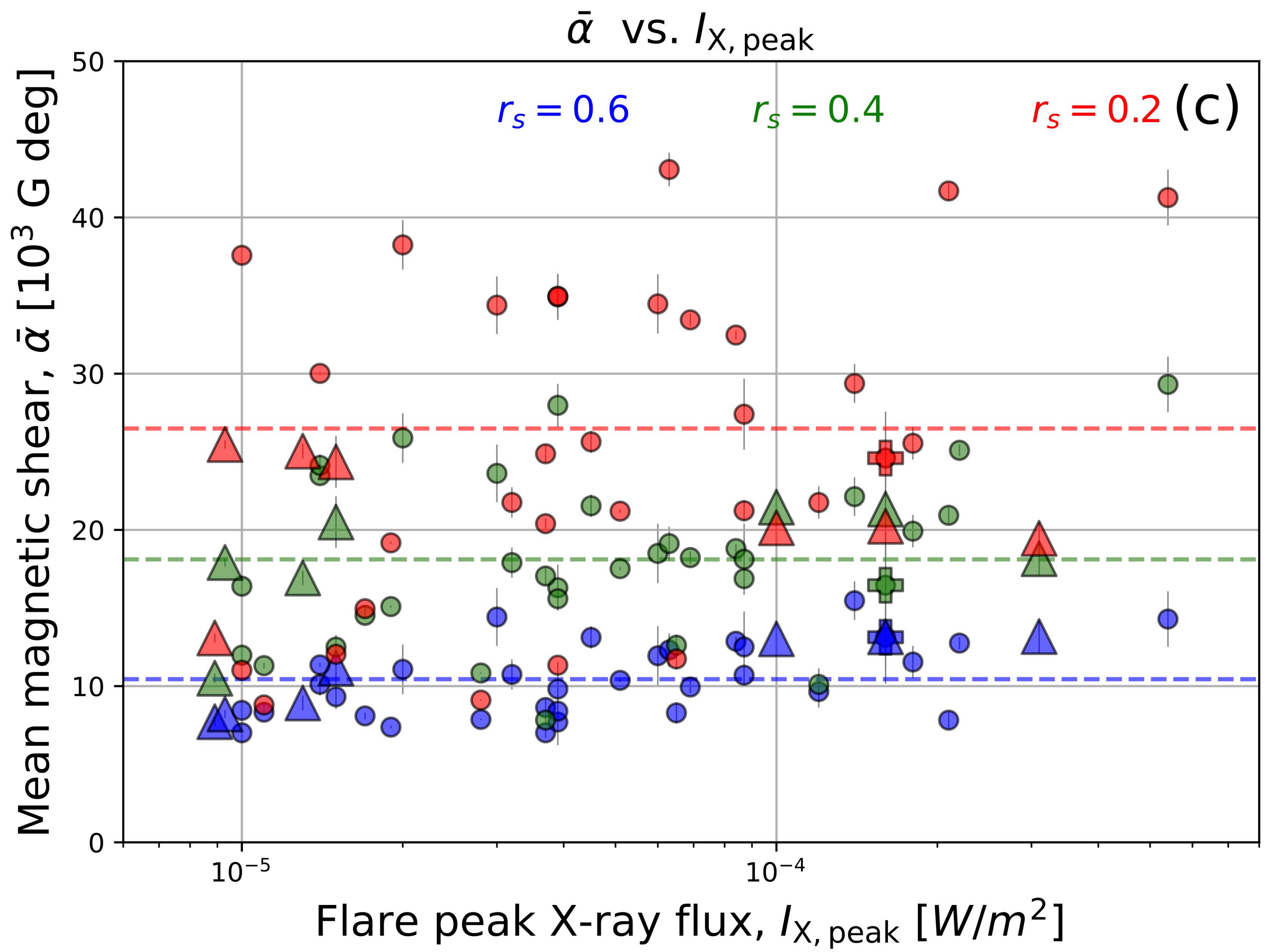
Mean Magnetic Shear

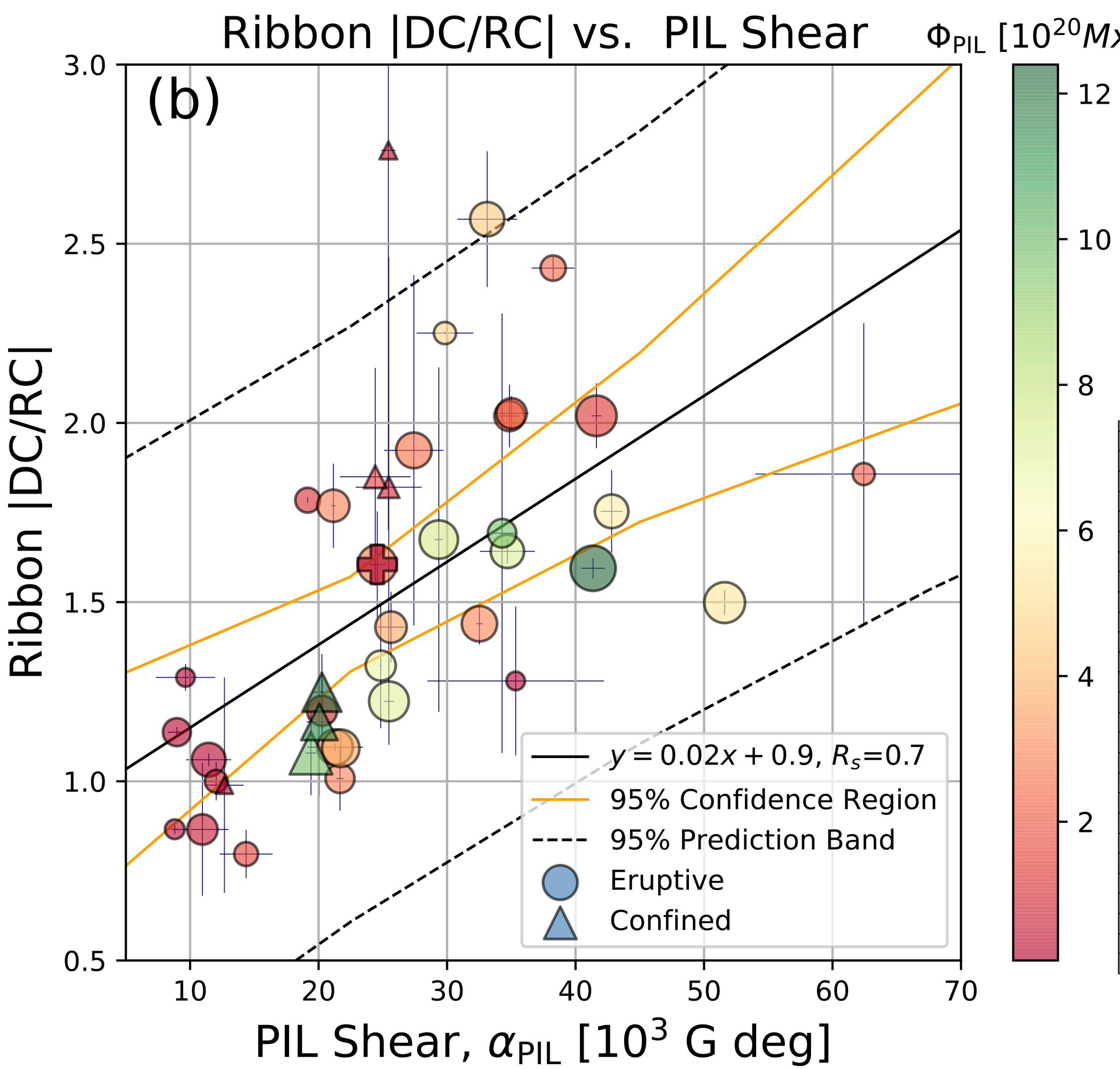
On the right: mean magnetic shear within AR, ribbon and PIL vs. flare peak X-ray flux:

We find:

- Mean shear increases from AR to ribbon and PIL areas.
- Weak correlation between shear and flare size.
- Confined flares (▲) have lower PIL shear.

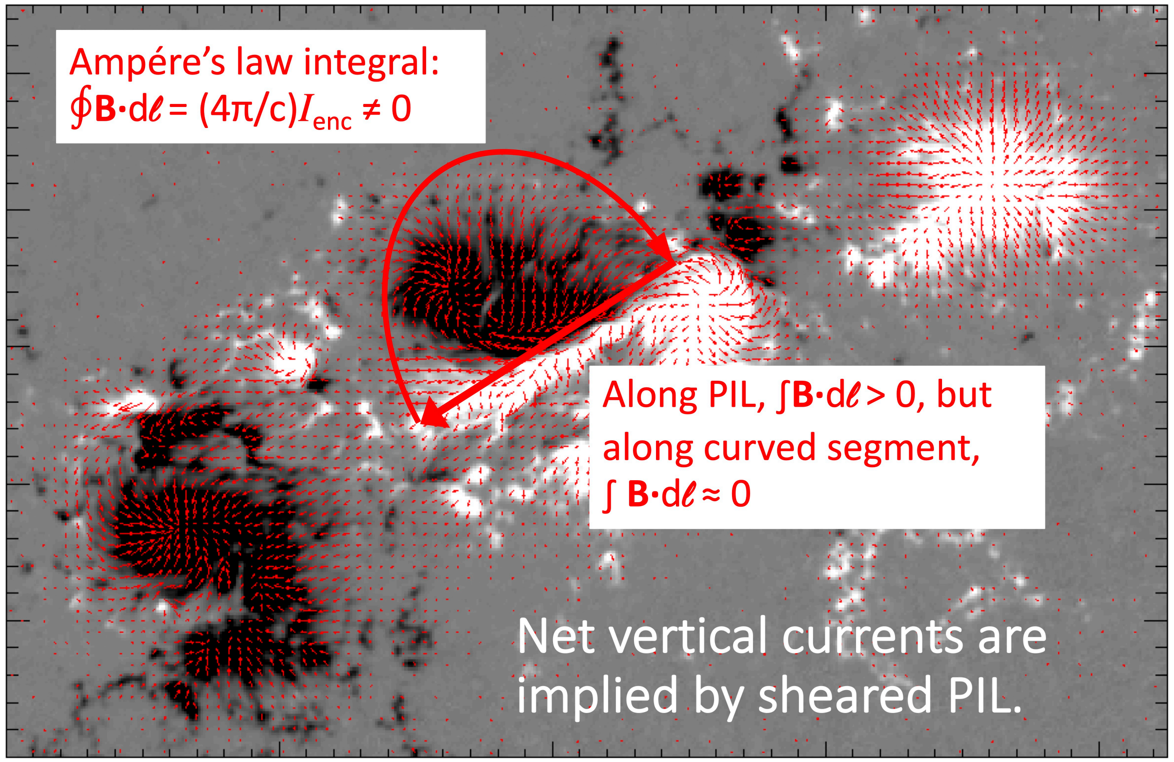


Net current proportional to shear at PIL



We find that vertical currents are

- Neutralized over AR as a whole,
- Non-neutralized over individual polarities,
- On the left: We find that net current within ribbon is proportional to the mean shear at PIL confirming earlier case studies & simulations



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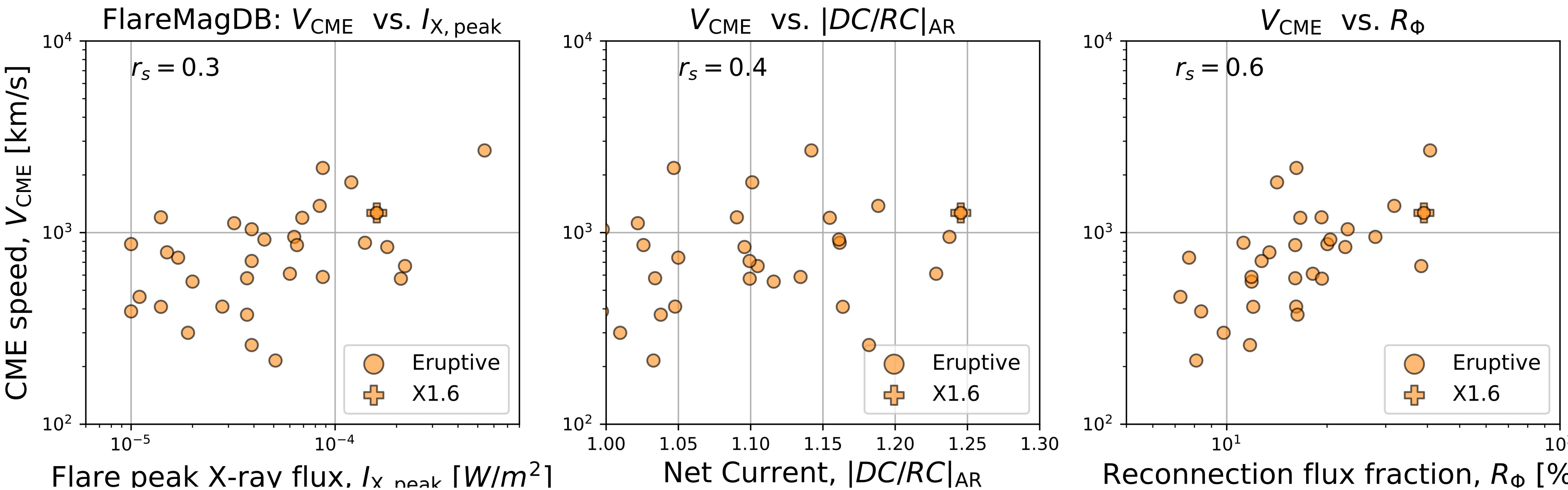
Eruptive vs. Confined Events



We find that for a given X-ray flux **confined** events have:

larger PIL fluxes,

lower PIL shear &

lower net current than eruptive events.

We find that for **eruptive** events:

CME speed has the strongest correlation with the reconnection flux fraction (rs=0.6) vs. flare peak X-ray flux (rs=0.3) or the net current (rs=0.4).

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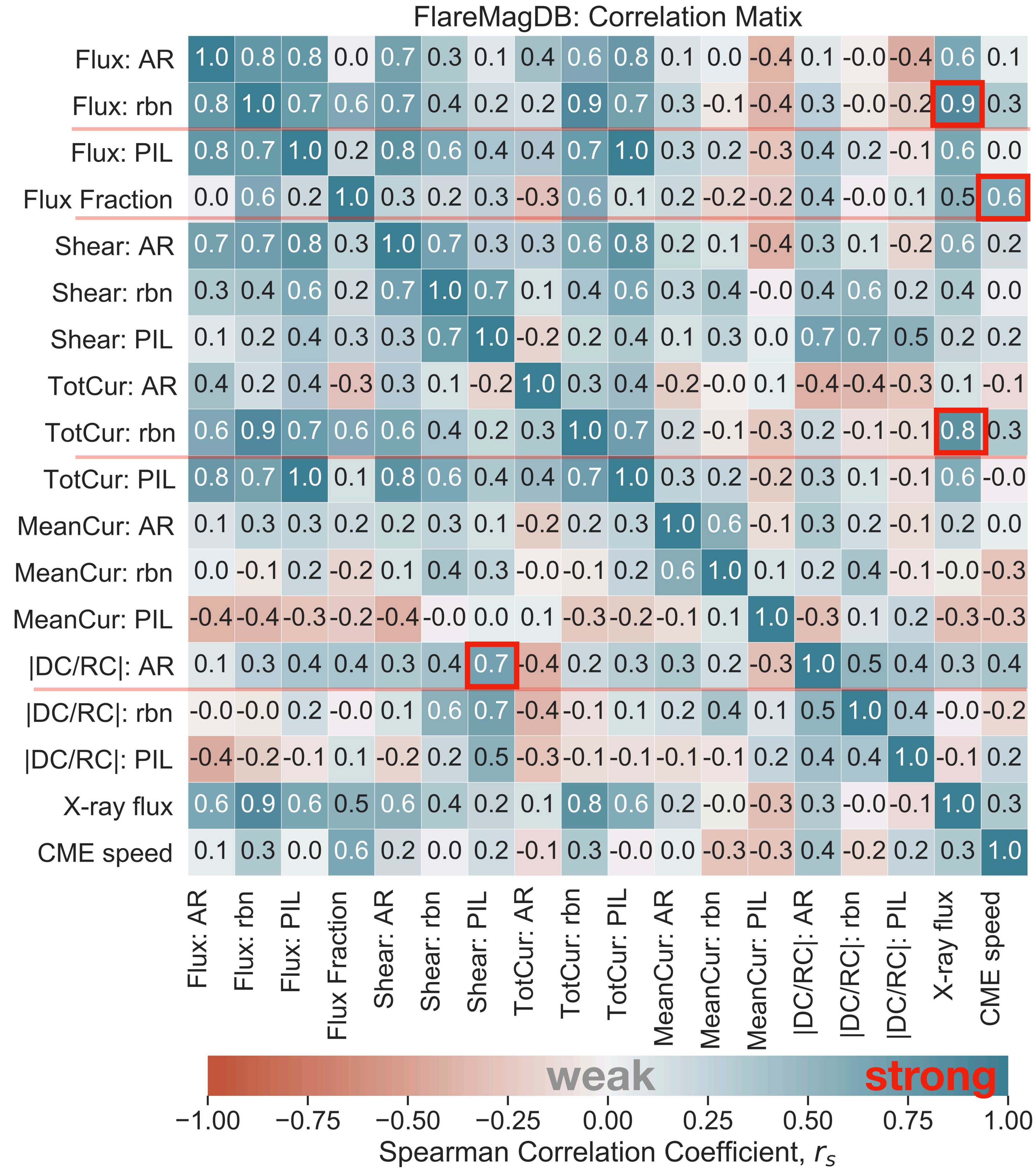
Which physical quantities correlate with others most?

- Let us look at correlation matrix with Spearman Correlation Coefficients.
- Quantities that correlate most with the <u>peak X-ray flux</u>:
    - Reconnection flux (0.9)
    - Total current within ribbons (0.8)
- Quantities that correlate most with the <u>CME speed</u>:
    - Reconnection flux fraction (0.6)
- Quantities that correlate most with the <u>net current</u>:
    - PIL shear (0.7)



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Conclusions

- Our analysis suggests that
  - **flare peak X-ray fluxes and CME speeds are guided by the total amount of magnetic flux that participates in the reconnection process and the amount of the overlying field**, rather than by the amount of PIL shear or AR net current.
  - **AR net current is proportional to the amount of shear at PIL** and is consistent with Ampere's law.
- As of know this study is the **largest statistical analysis of flare vector magnetic fields within ribbon and PIL areas**. Such approach is beneficial since it enables us to investigate general trends that may be overlooked in case studies of individual events.
- Thank you! Questions? Email me!