Magnetic Feature Tracking and the Small-Scale Solar Dynamo

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Outline

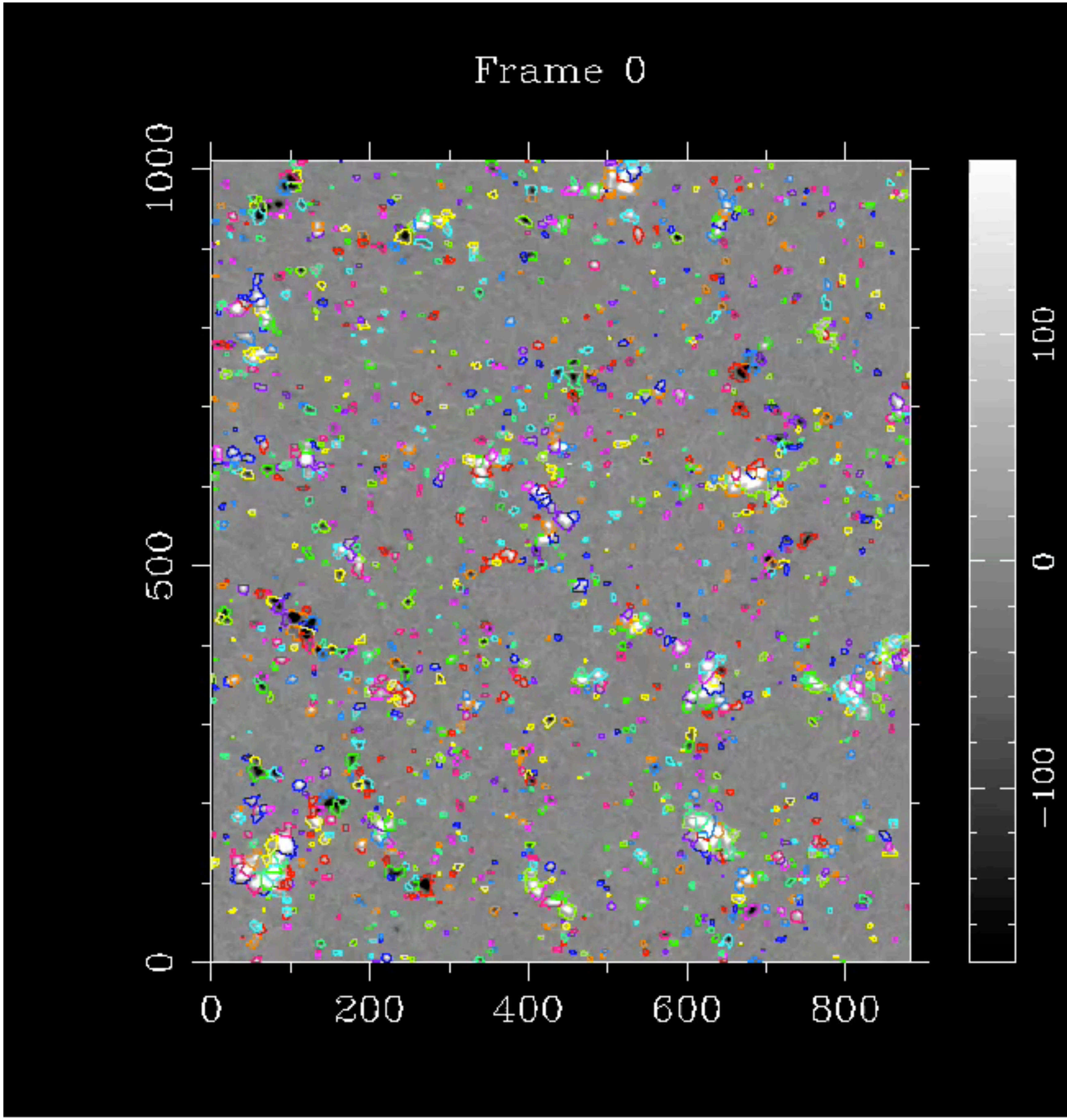
- ➡ Magnetic “features”: what they are and why they are useful
- Feature-keyed cluster analysis in Hinode NFI magnetograms (“Spatial Nonlocality of the Small-Scale Solar Dynamo” Lamb, Howard & DeForest, ApJ 2014)
- Conclusions

Feature: “a visually identifiable part of an image.”

Detecting and tracking magnetic features at small spatial scales

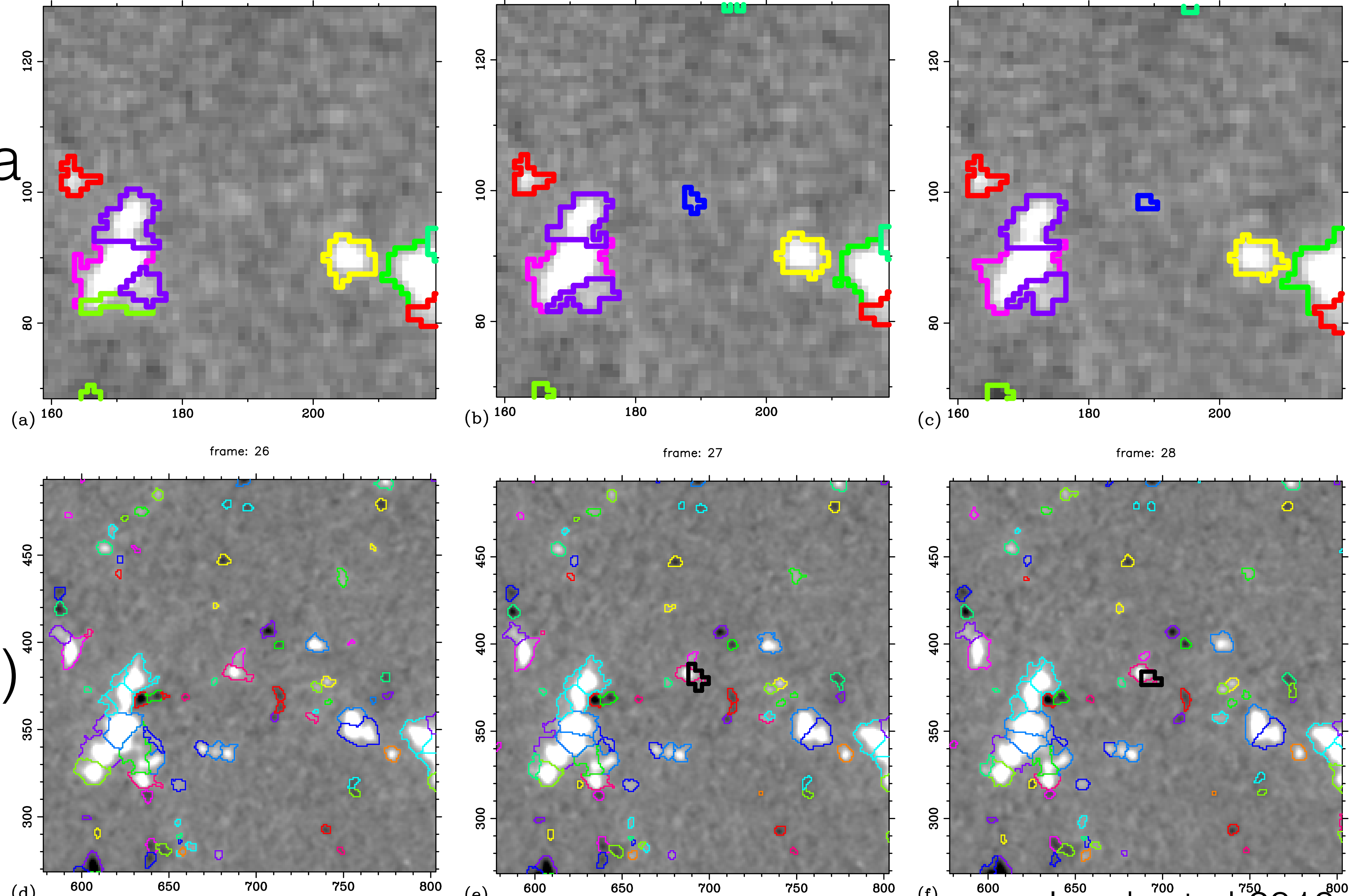
We can do this for ~10^7 features.

Enables detailed statistical tests that can’t be done visually.



Low-res data (MDI-HR)

Hi-res data (Hinode NFI)



Lamb et al 2010

Small, weak features in low-res data are REAL

1) detection and tracking are robust

2) same phenomena in the higher-resolution data

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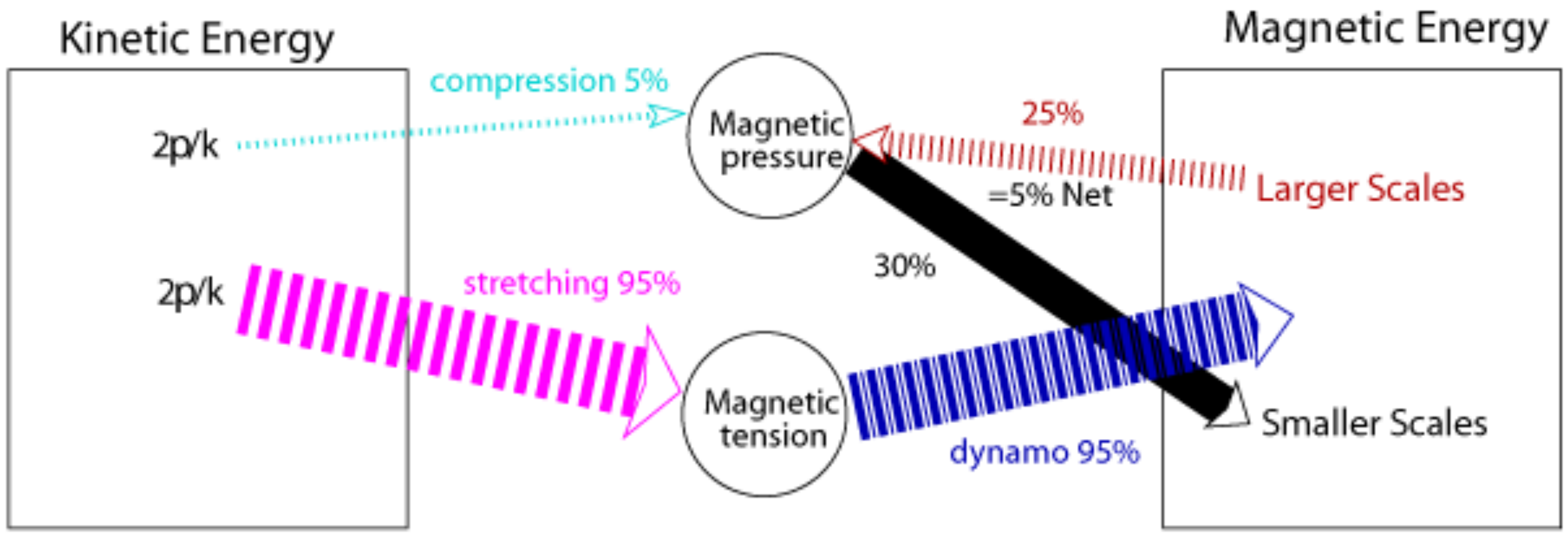
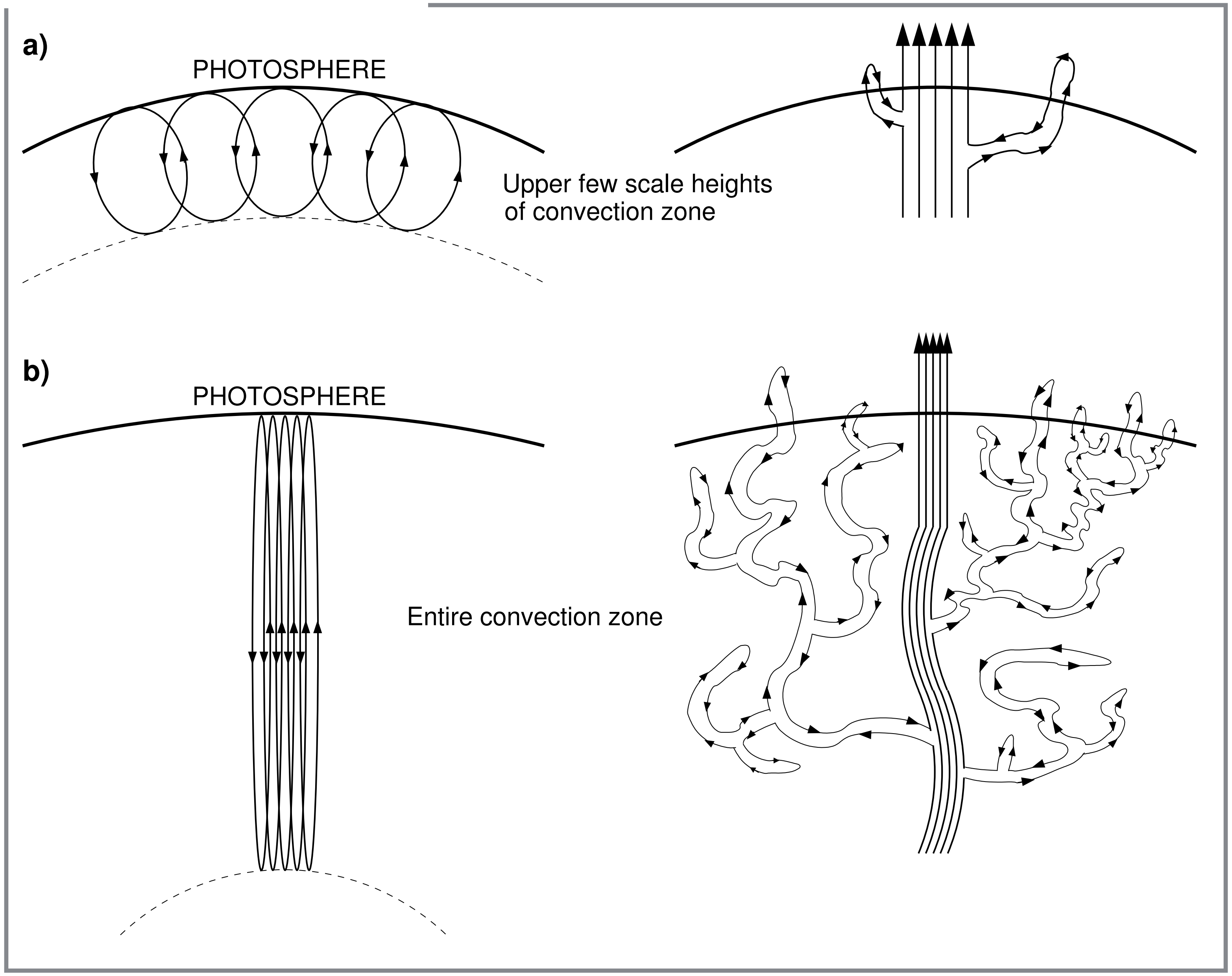
- Conclusions & Future Directions

Dynamos work by stretching magnetic fields

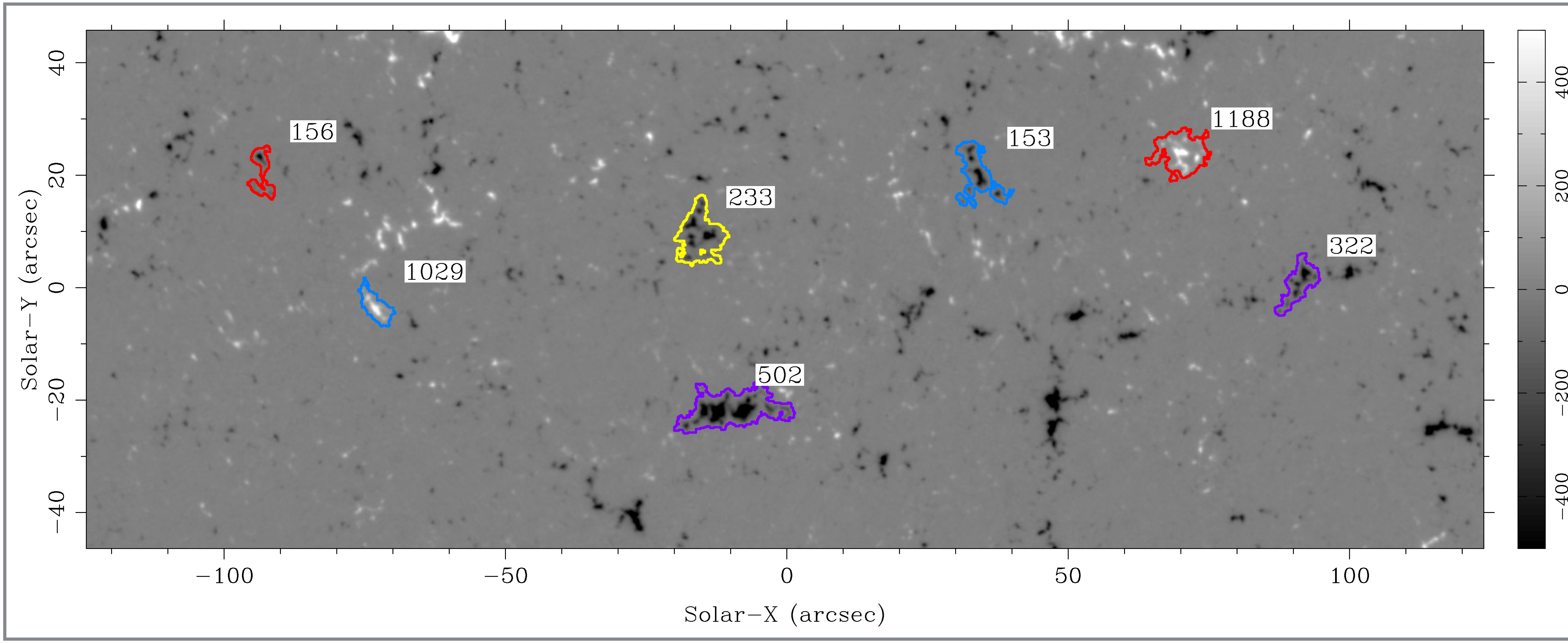


Pietarilla Graham et al 2010

Do we see evidence of this stretching, and what does this tell us about the dynamo?



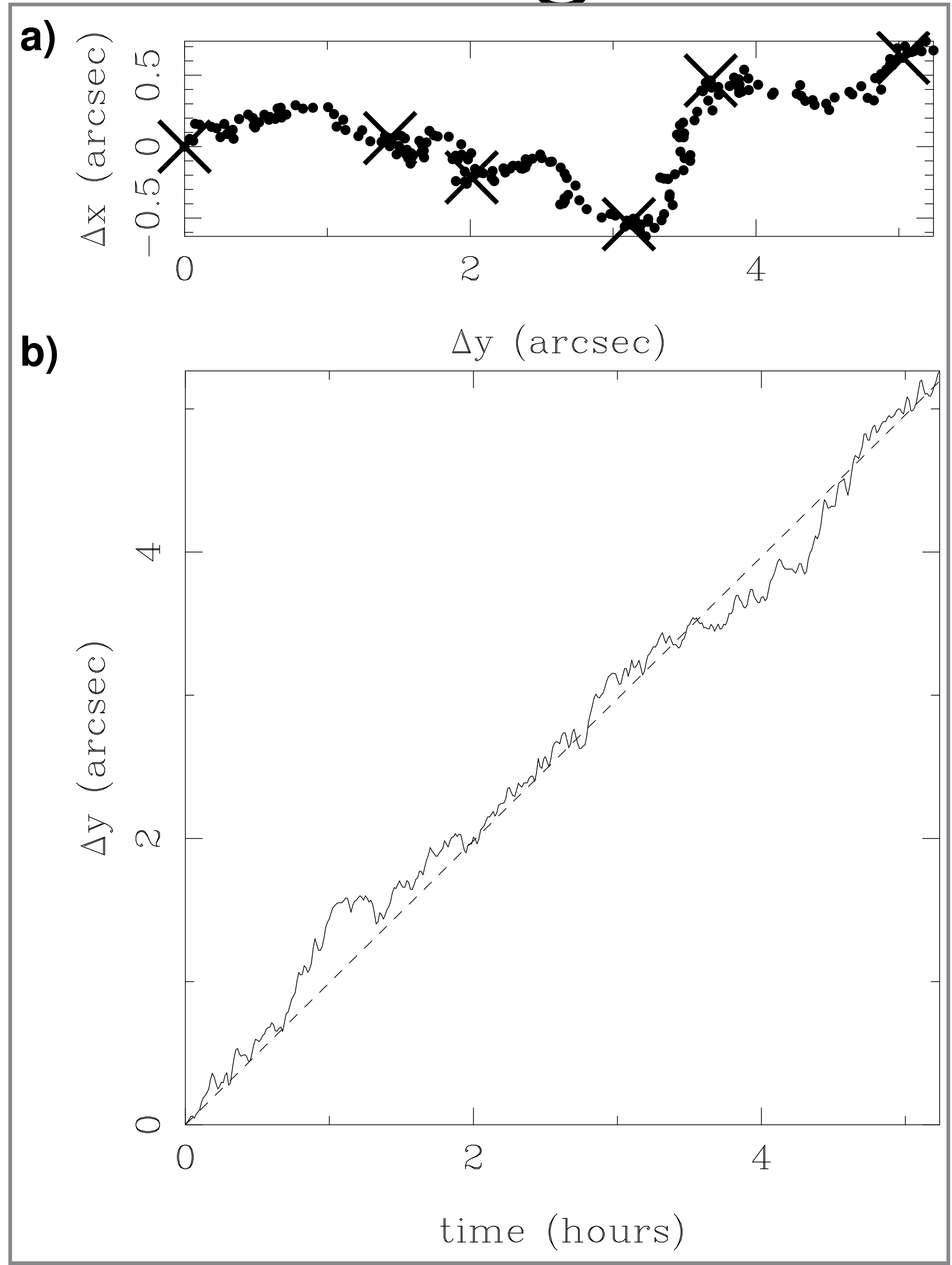
Lamb, Howard, & DeForest 2014



- Search for clustering around long-lived supergranular network concentrations (NCs).
- Hinode data: 5.25 hr NFI magnetogram sequence, 2007 September 19, quiet sun near disk center.
- >1E5 features found
- Identify NCs: 1) present for entire dataset; 2) peak flux density > 500 G in frame 0; 3) avoid edge effects.

Stabilizing the NFI images

- Unexpected use of the tracking data
- Find median interframe x- and y- feature motions
- Enables meaningful spatial comparisons across the dataset



Spatial Clustering Analysis

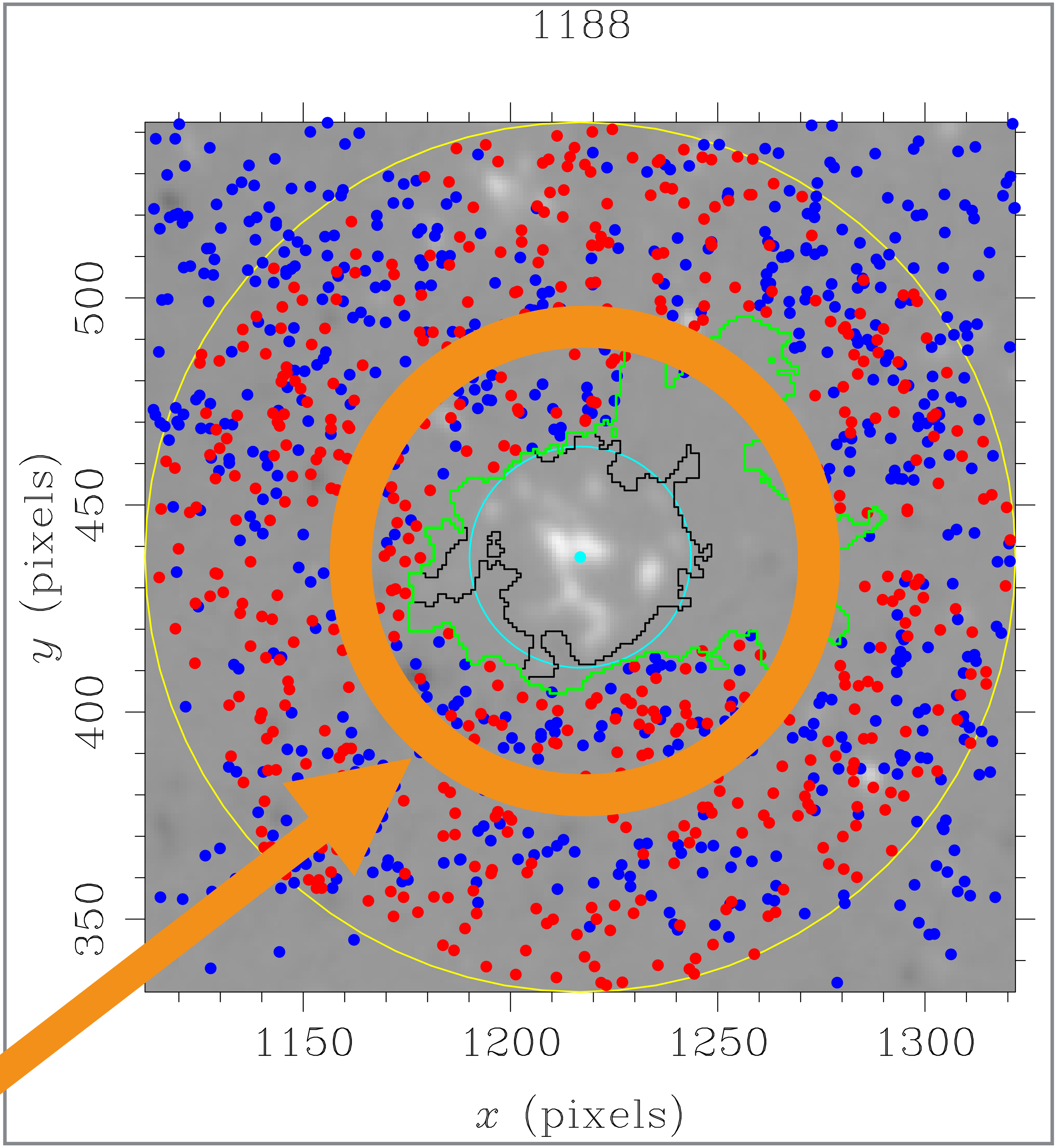
- Common in health & environmental sciences: Given the locations of some events/objects, are they more or less likely to be near other events/objects (of the same or different type)?
- e.g., John Snow's 1854 Broad Street (London) cholera outbreak investigation

Analysis of feature birth locations near existing strong field

blue = detected feature births (excl. splittings)

red = Monte Carlo simulations

red dots = # blue dots between green perimeter and yellow circle



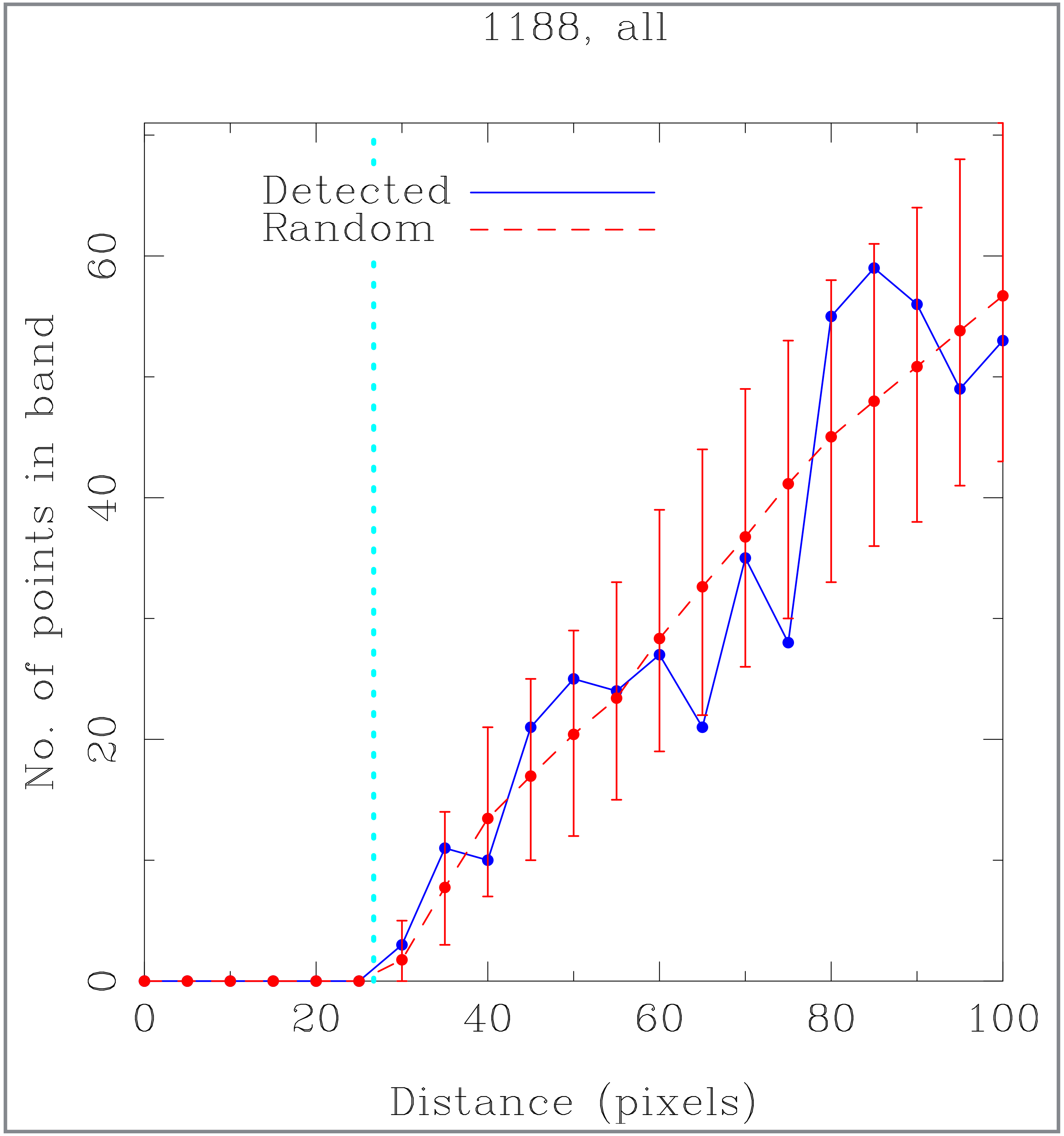
Do 10^4 iterations per NC

Count # of features in the annulus

Lamb et al 2014

Count the number of Monte Carlo points (red) and detected features (blue) in a 5-pixel wide annulus.

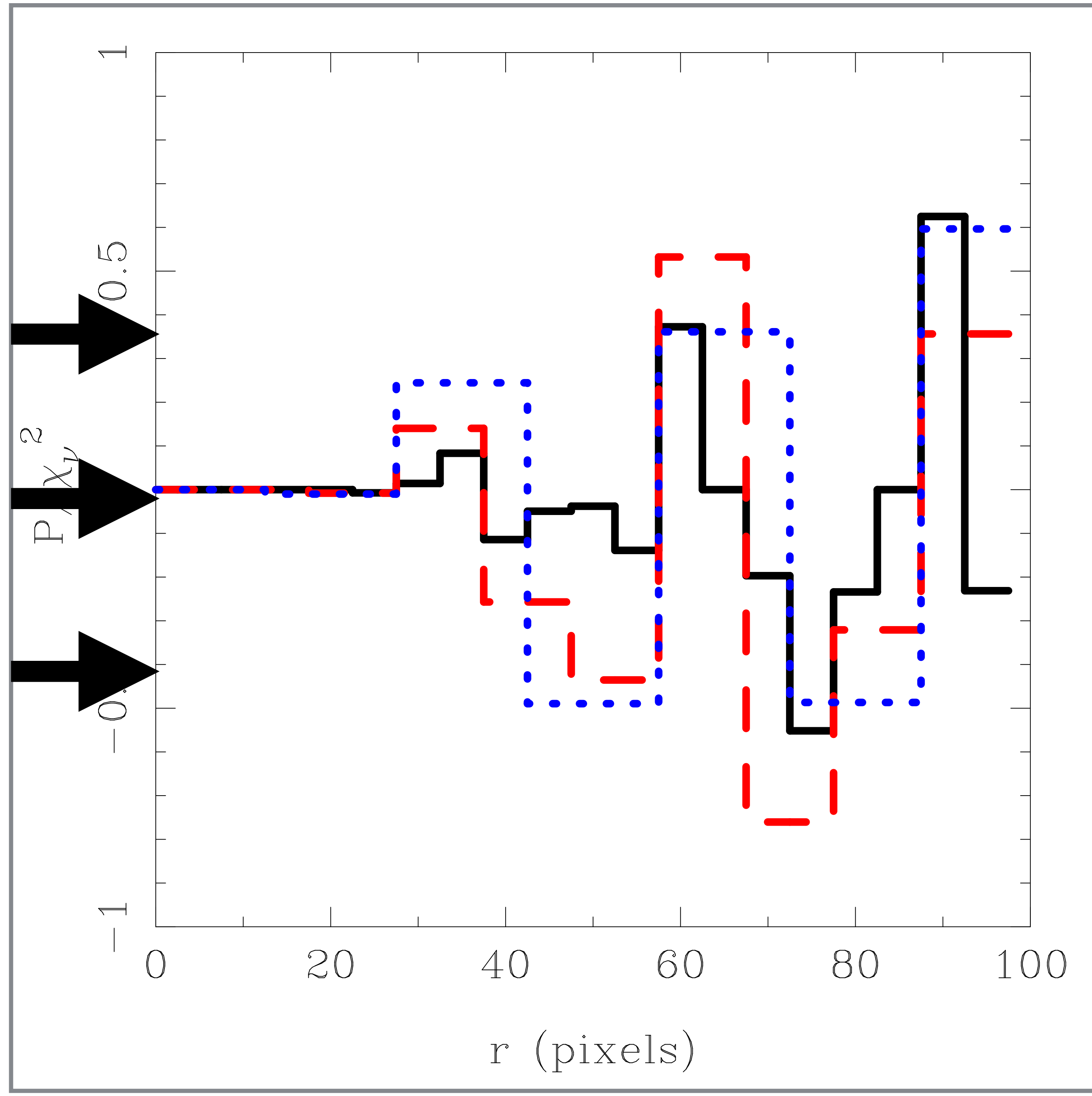
Repeat for 10- and 15-pixel widths



# of detected features at
some distance:
was more than most MC sims

was ~the same as MC sims

was less than most MC sims

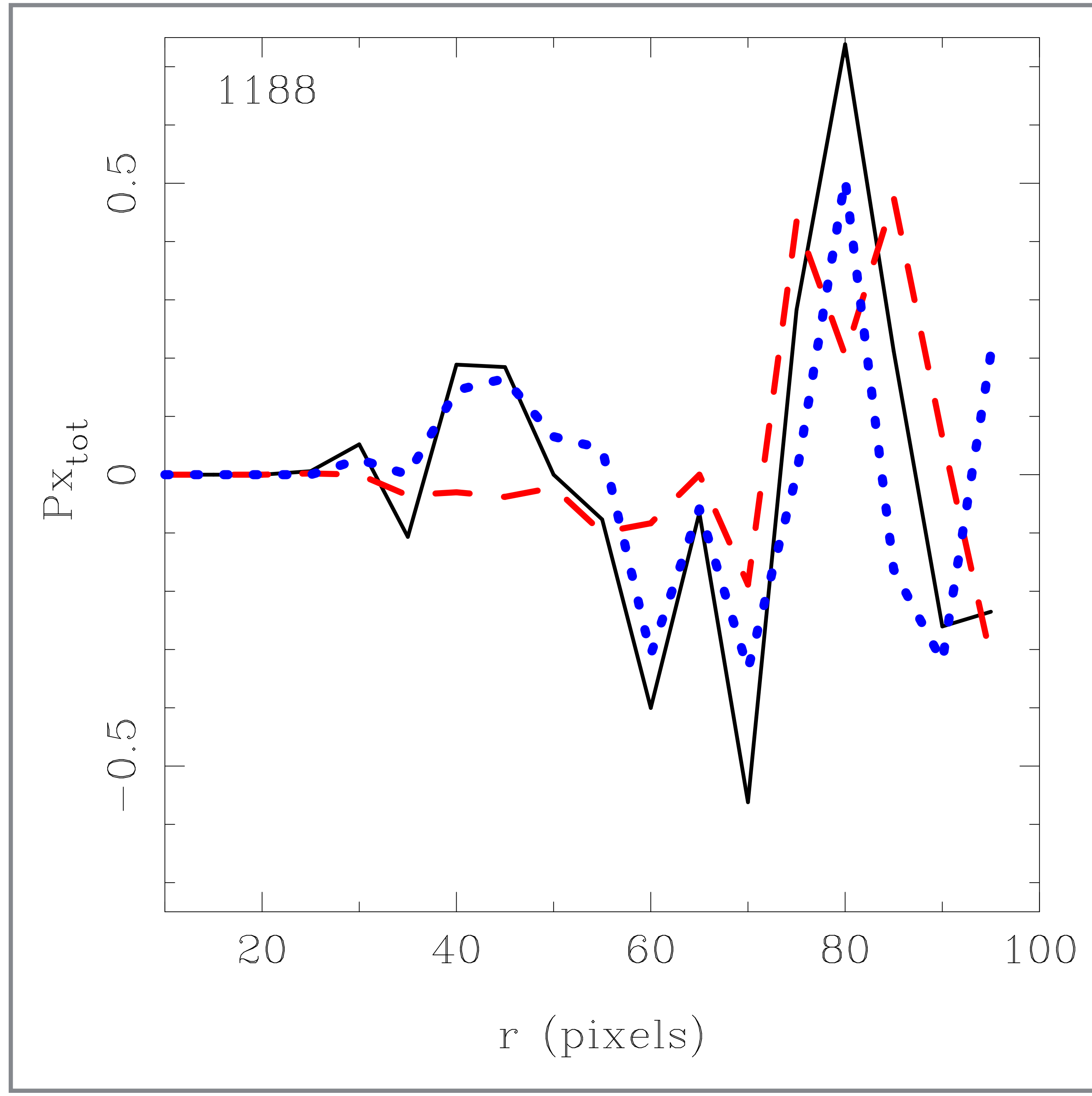


Colors/line styles correspond to different annulus widths

- A problem with histograms & binning: how wide to make the bins?

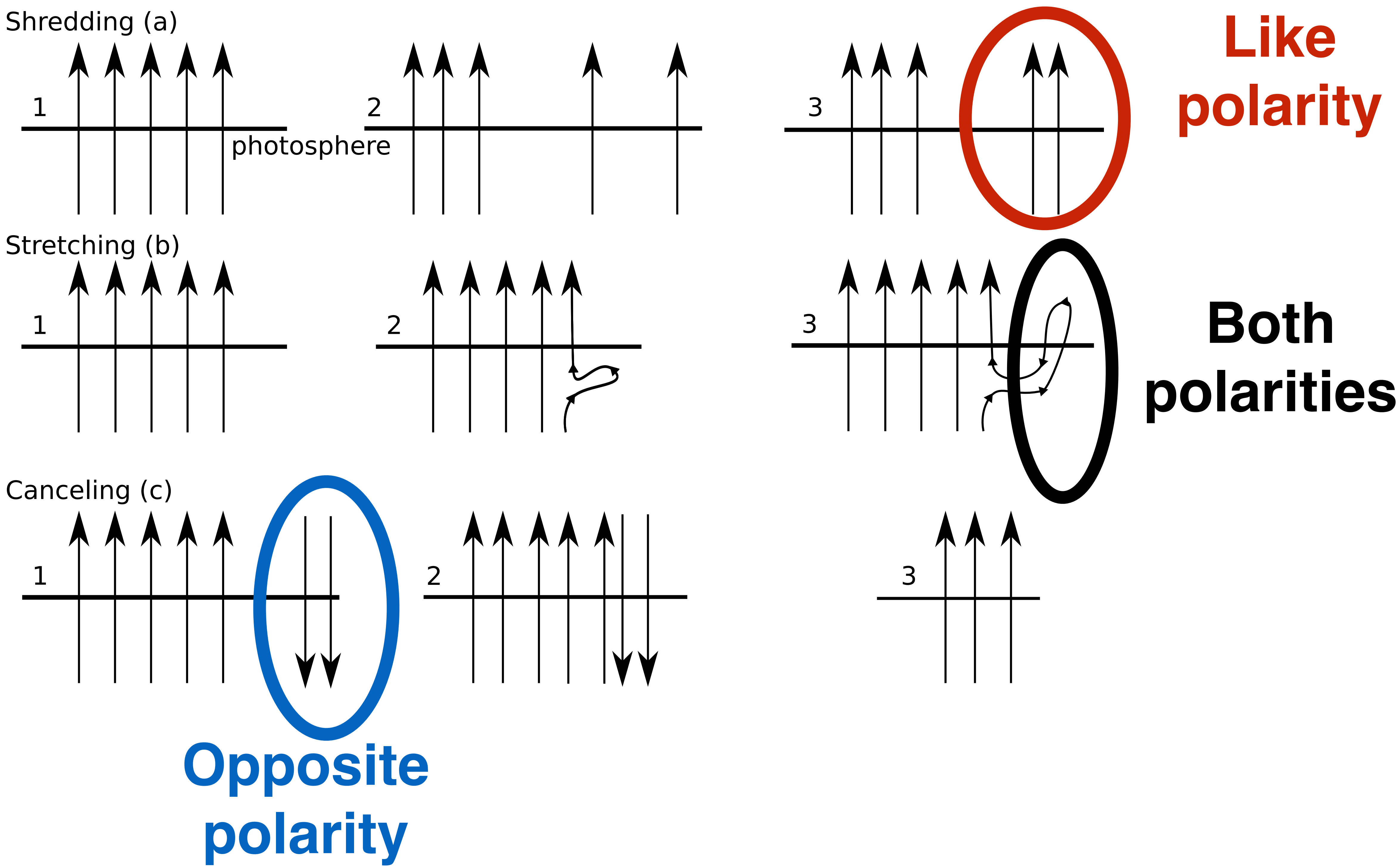
- Result should be independent of the bin width
- Sum previous slide's curves to make black curve here: a composite

- Aside: next time don't use histograms!



Black solid: all features
Red dashed: same polarity as NC
Blue dotted: opposite polarity as NC

Flux concentration evolution should have measurable signatures in the polarity of nearby features



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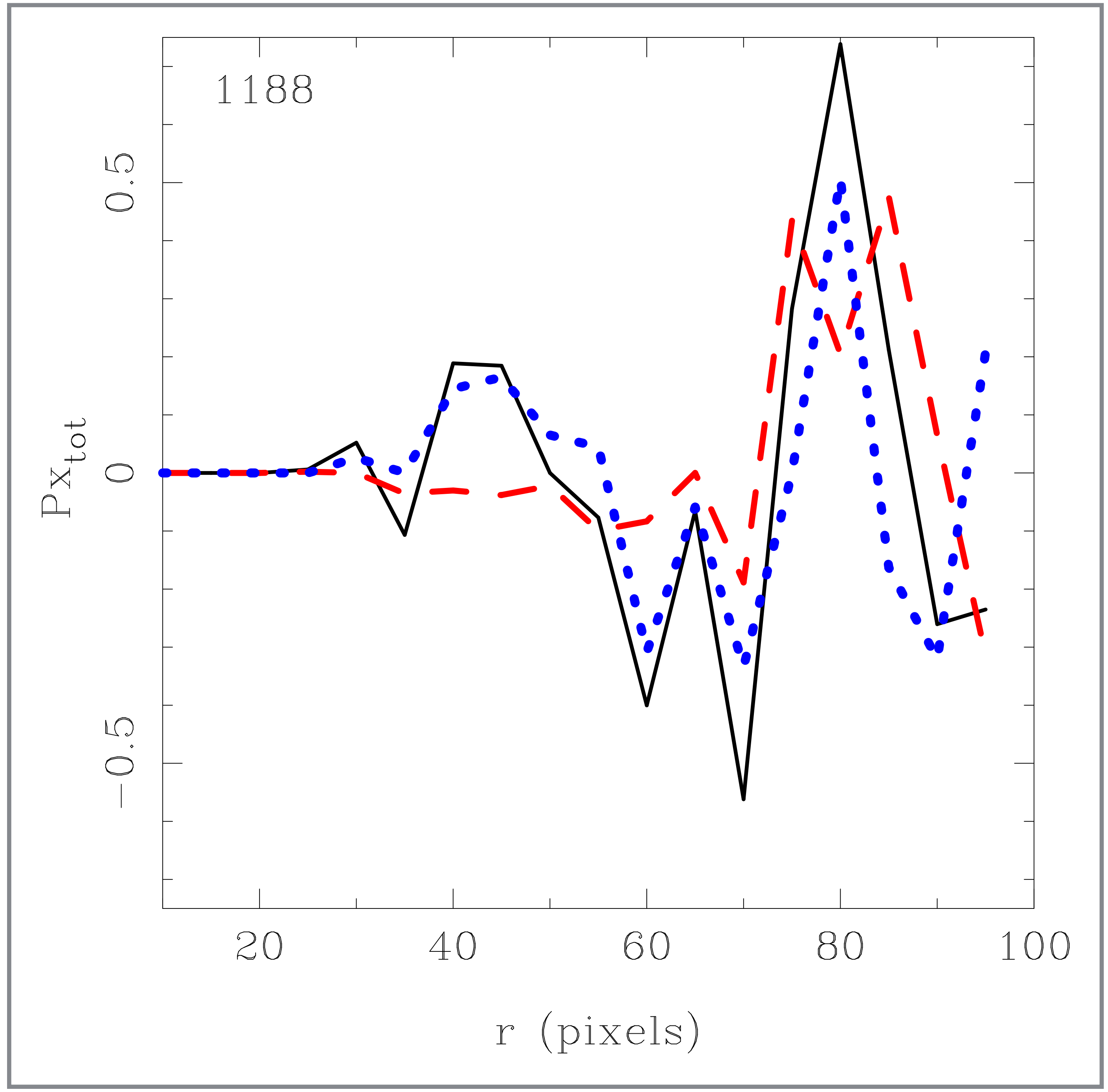

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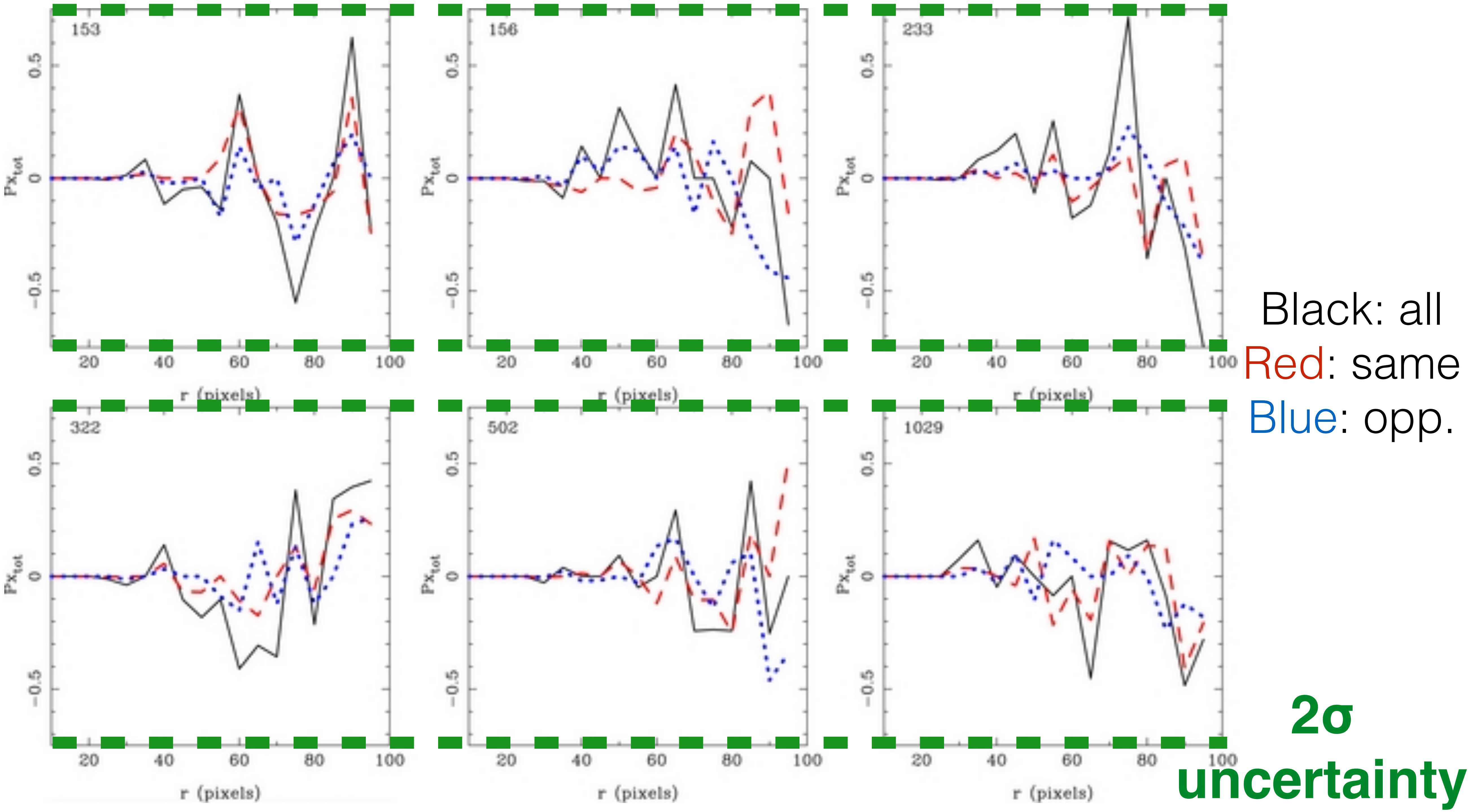
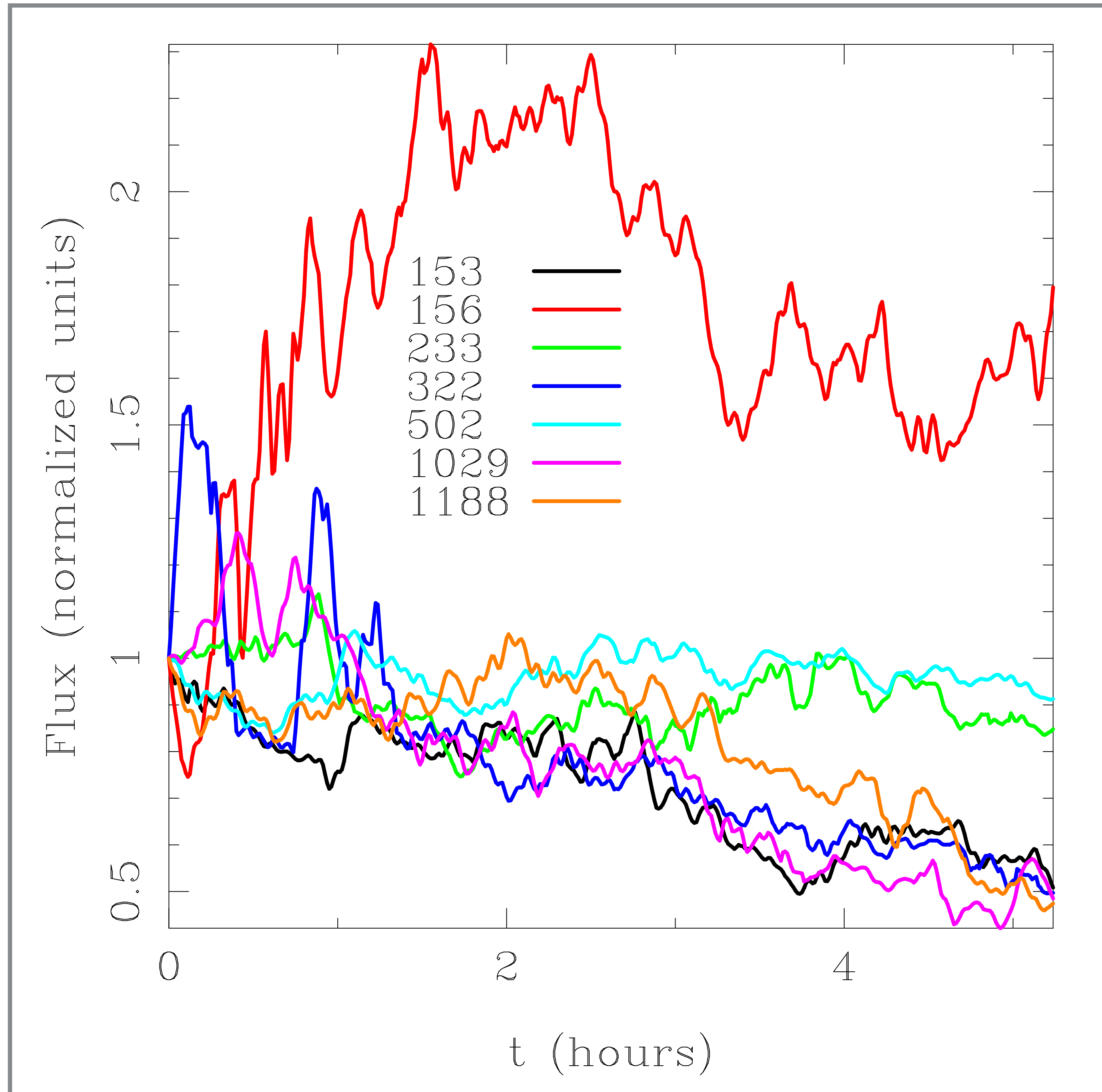


Repeat for the other 6 NCs…
No location where new features are more likely to be born (across all different regions)

So what is all that small-scale field doing around the NCs?

- Evolving the network fields, like you might expect!
- 4 of 7 NCs lose ~50% of their initial flux in 5 hours
- See Milan Gosic's poster for great examples of this



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Conclusions & Future Directions

- Dynamos require stretching of magnetic field lines, but no direct, systematic evidence of this yet for the small-scale dynamo at 3—12 Mm scales.

- MURaM simulations predict stretching peaks at ~100 km scales (== 1 Hinode pixel!), significant contributions up to 1 Mm scale.

- Our clustering technique is robust but needs to be applied to the smallest observed features & compared with simulations.