SOLAR FLARE PREDICTION IN A NUTSHELL

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11TH EUROPEAN SPACE WEATHER WEEK
NOVEMBER 17-21 2014, LIEGE, BELGIUM

Splinter Session on Solar Storms:
Flares, CMEs and SEP Events

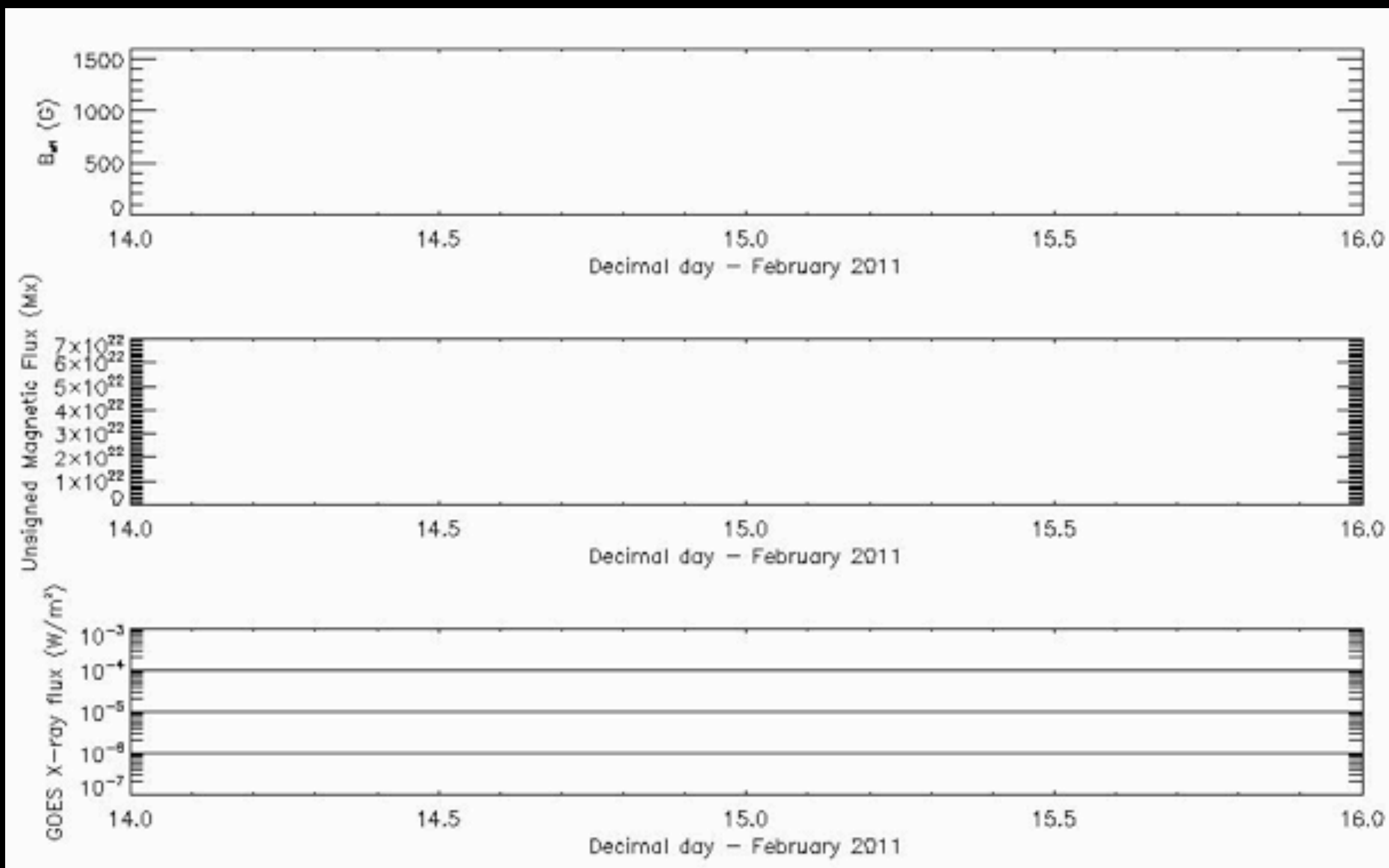
Liege, Belgium, 17 - 21 November 2014

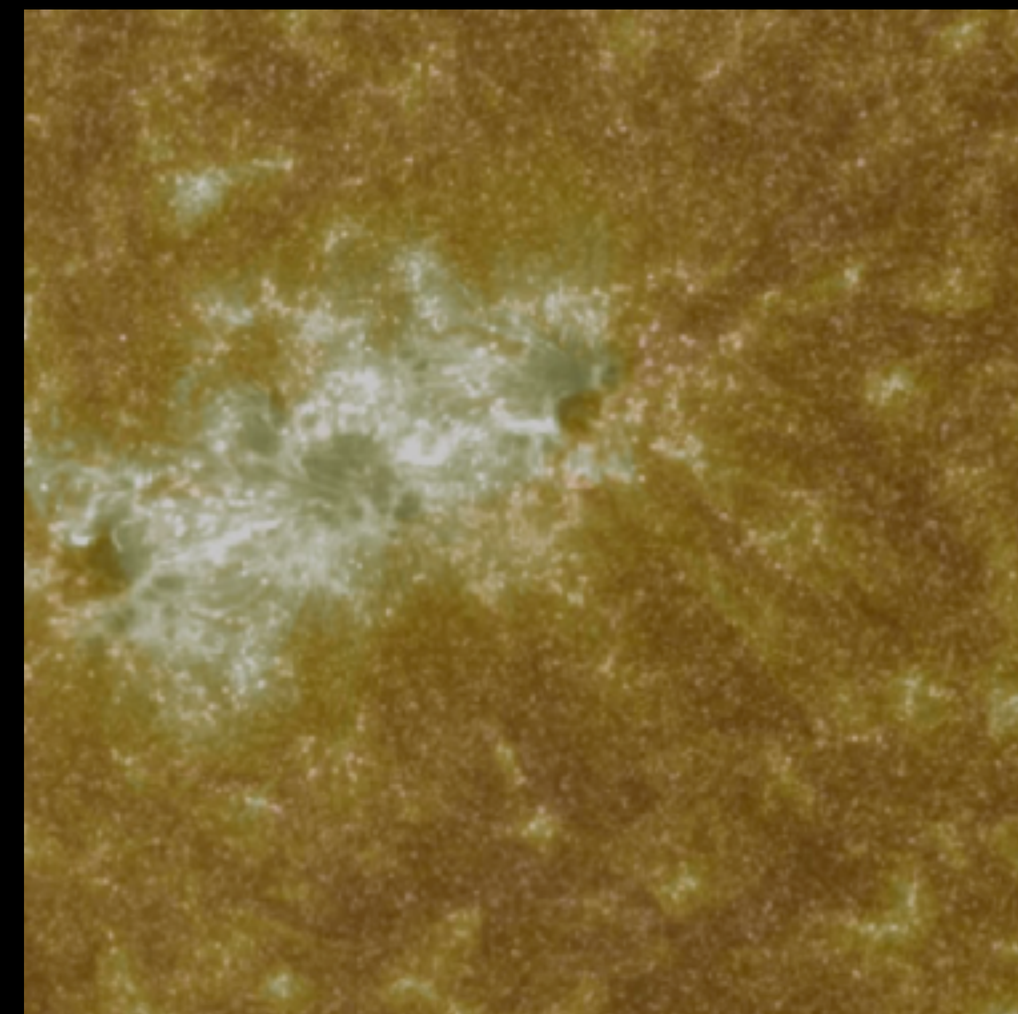
OUTLINE

- Where should we look for flares?
- How frequent (or rare) are major flares?
- Proposed flare prediction methods
- An encapsulation of results
- Gaps in understanding / knowledge
- Needs for an efficient prediction
- Conclusion

WHERE DO FLARES OCCUR?

NOAA AR 11158, 14 - 16 February, 2011





Flares of class-C and above occur in solar active regions

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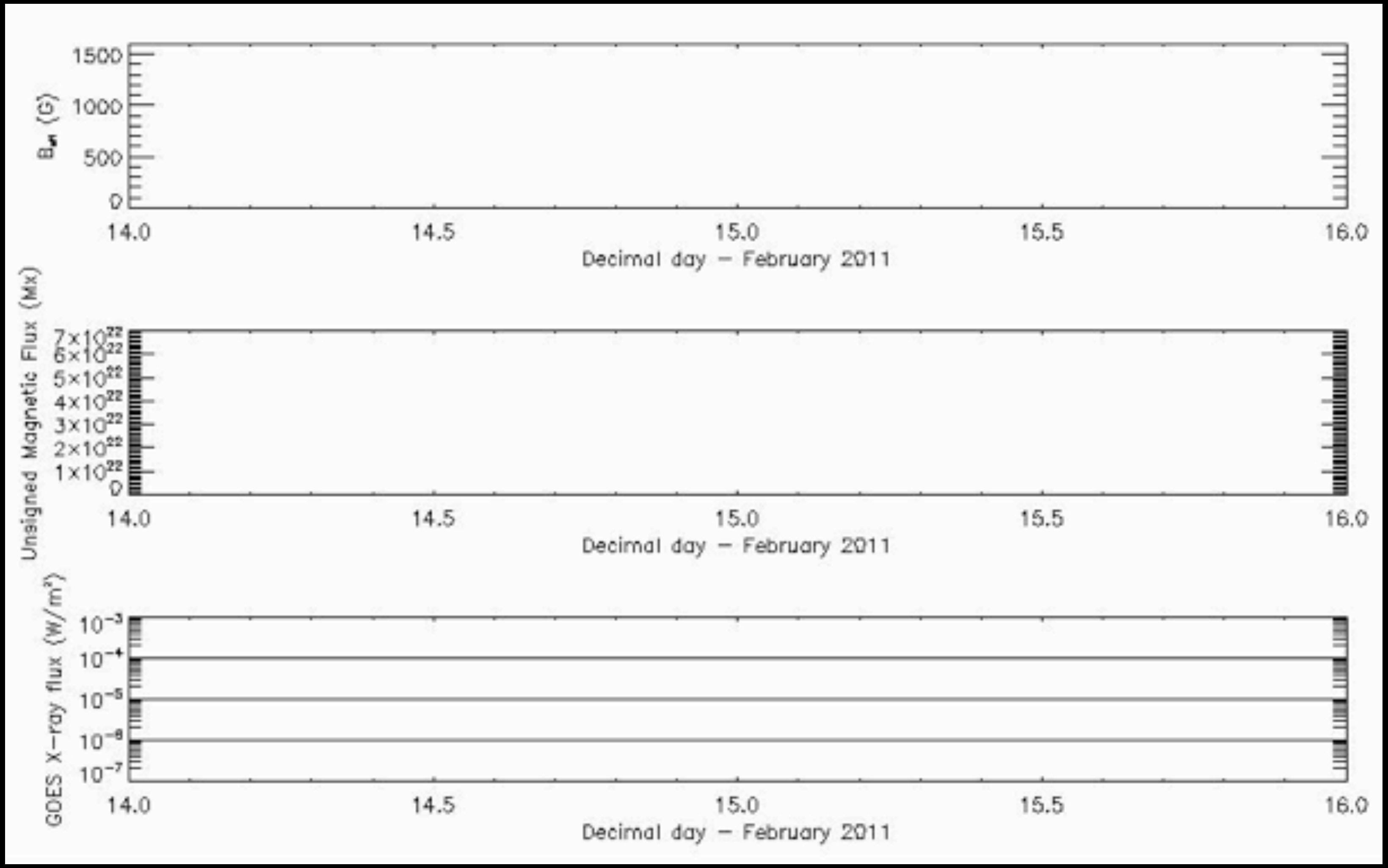

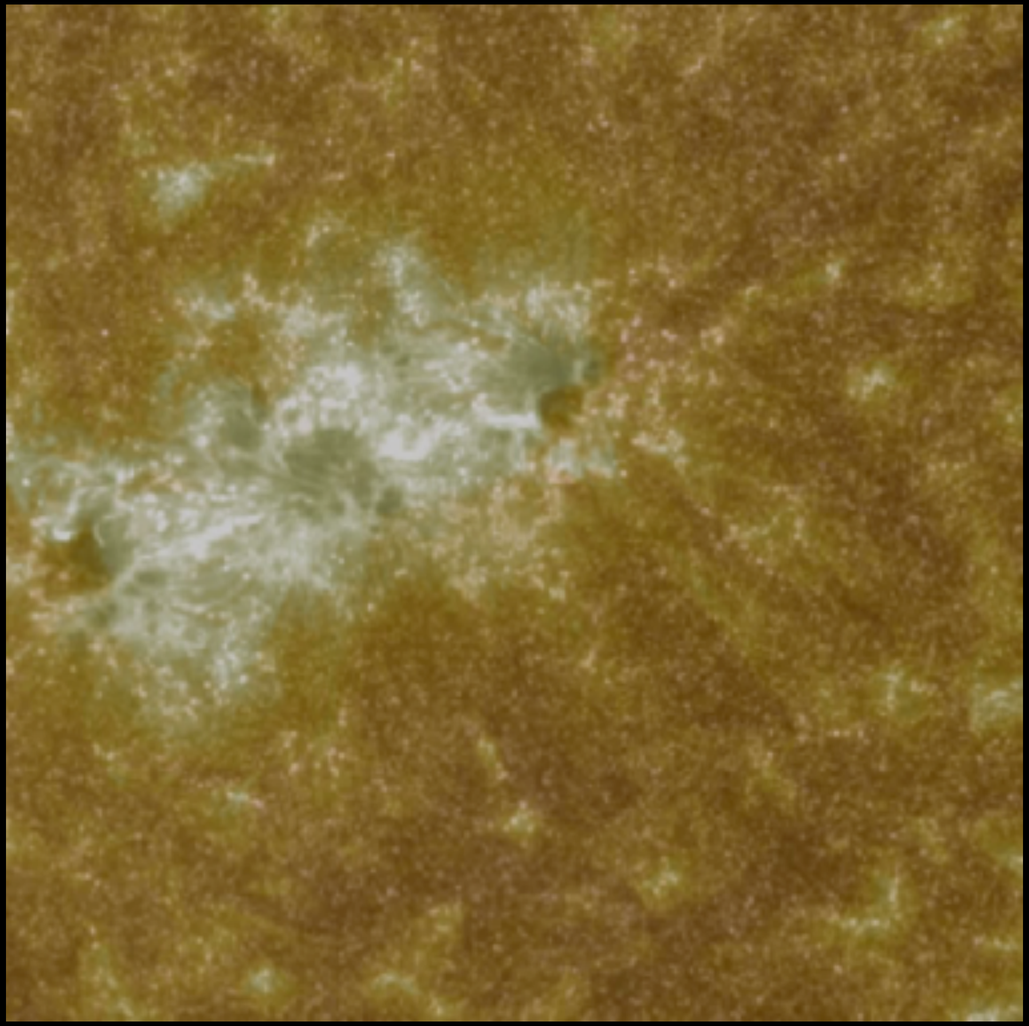

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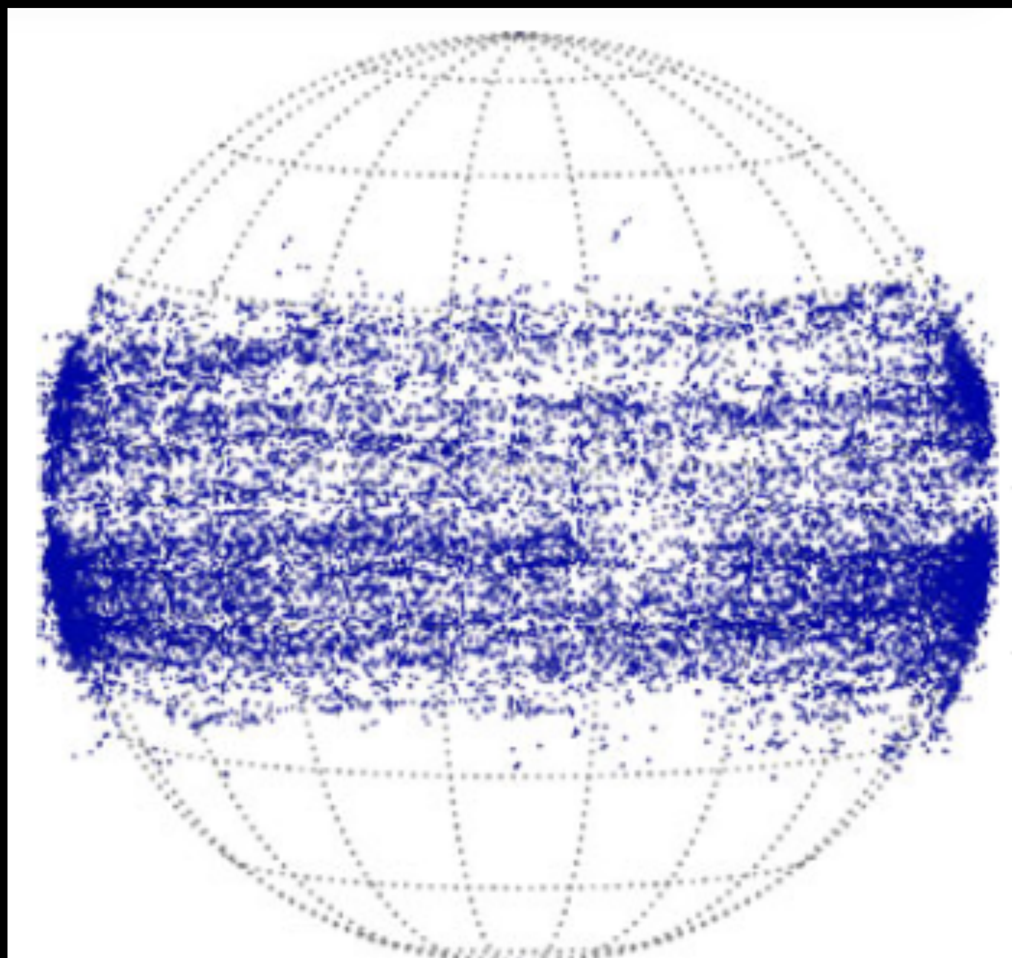
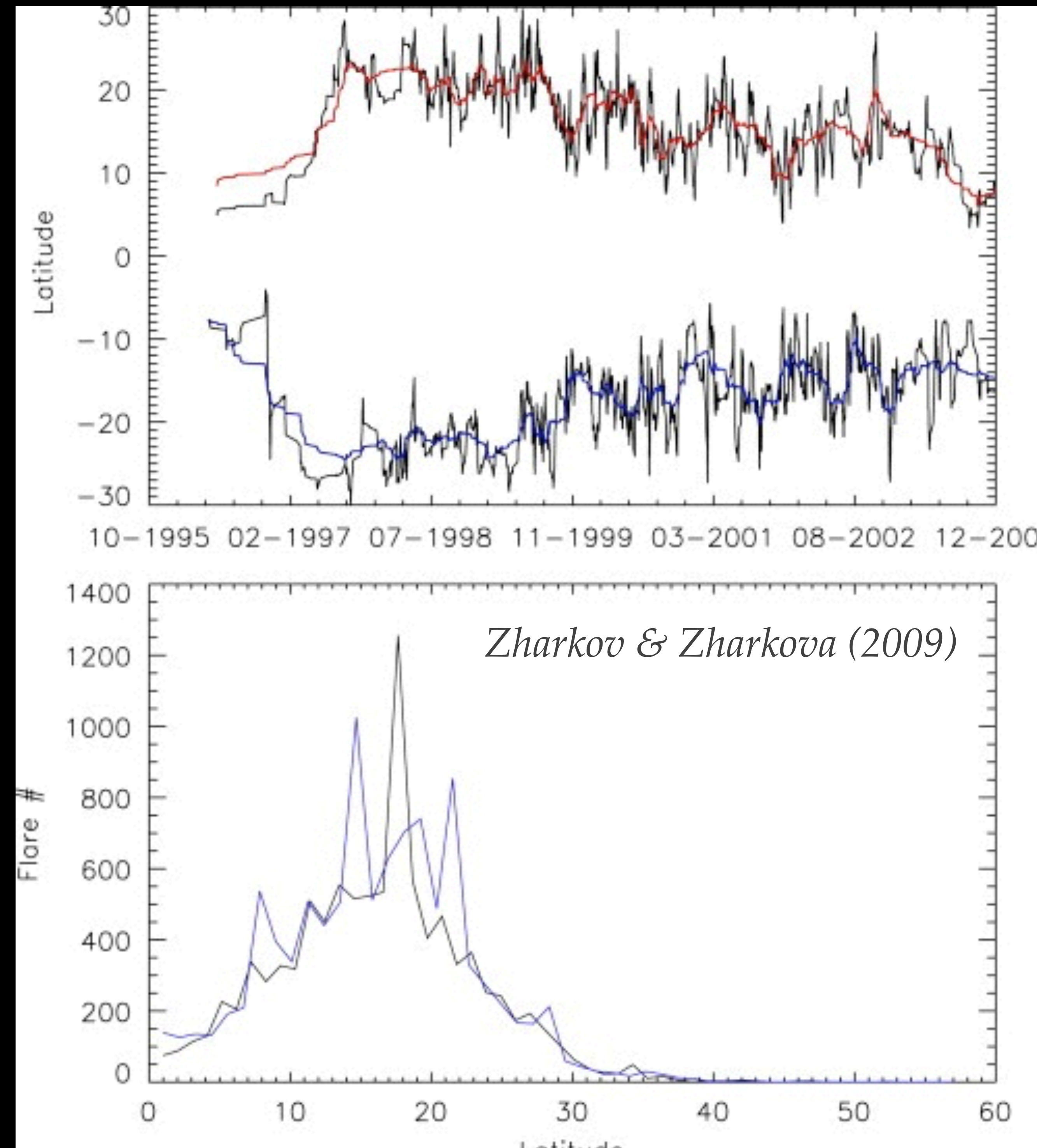
ACTIVE REGIONS: FLARE “HOTSPOTS”



Christe et al. (2008); Hannah et al. (2011)



Zharkov & Zharkova (2009)

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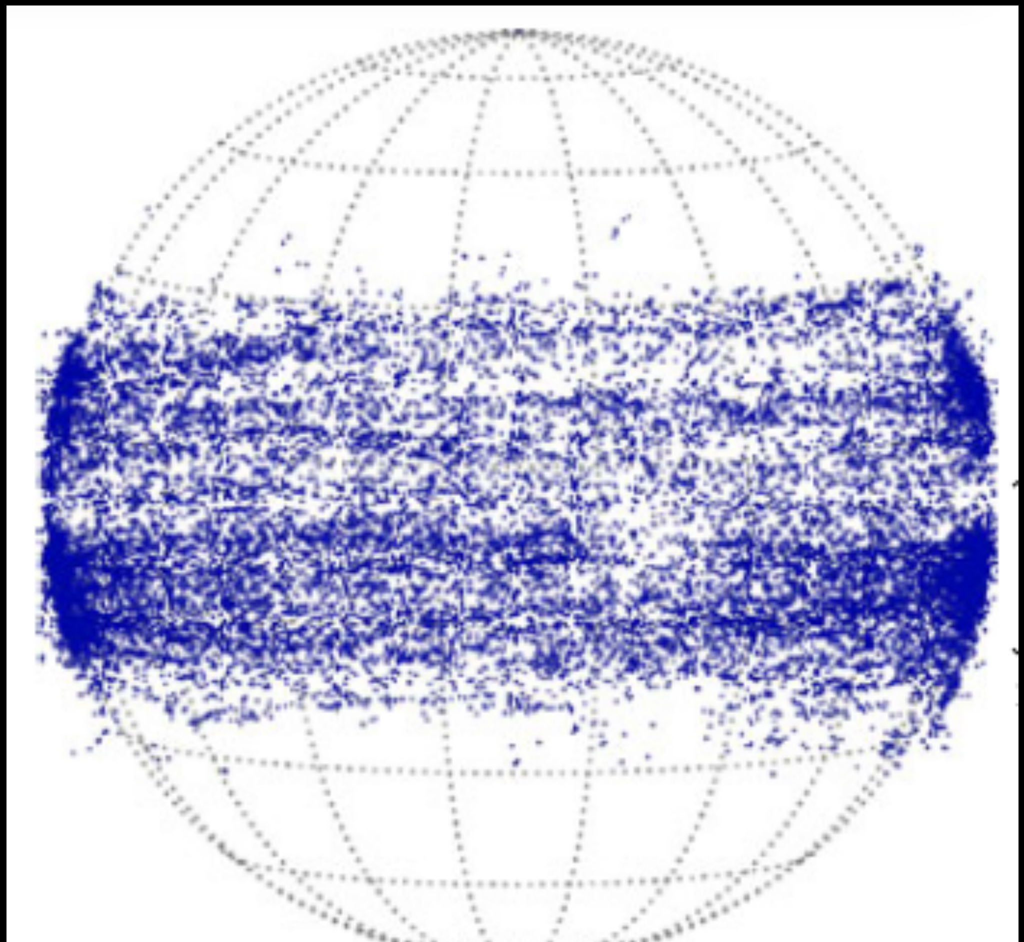
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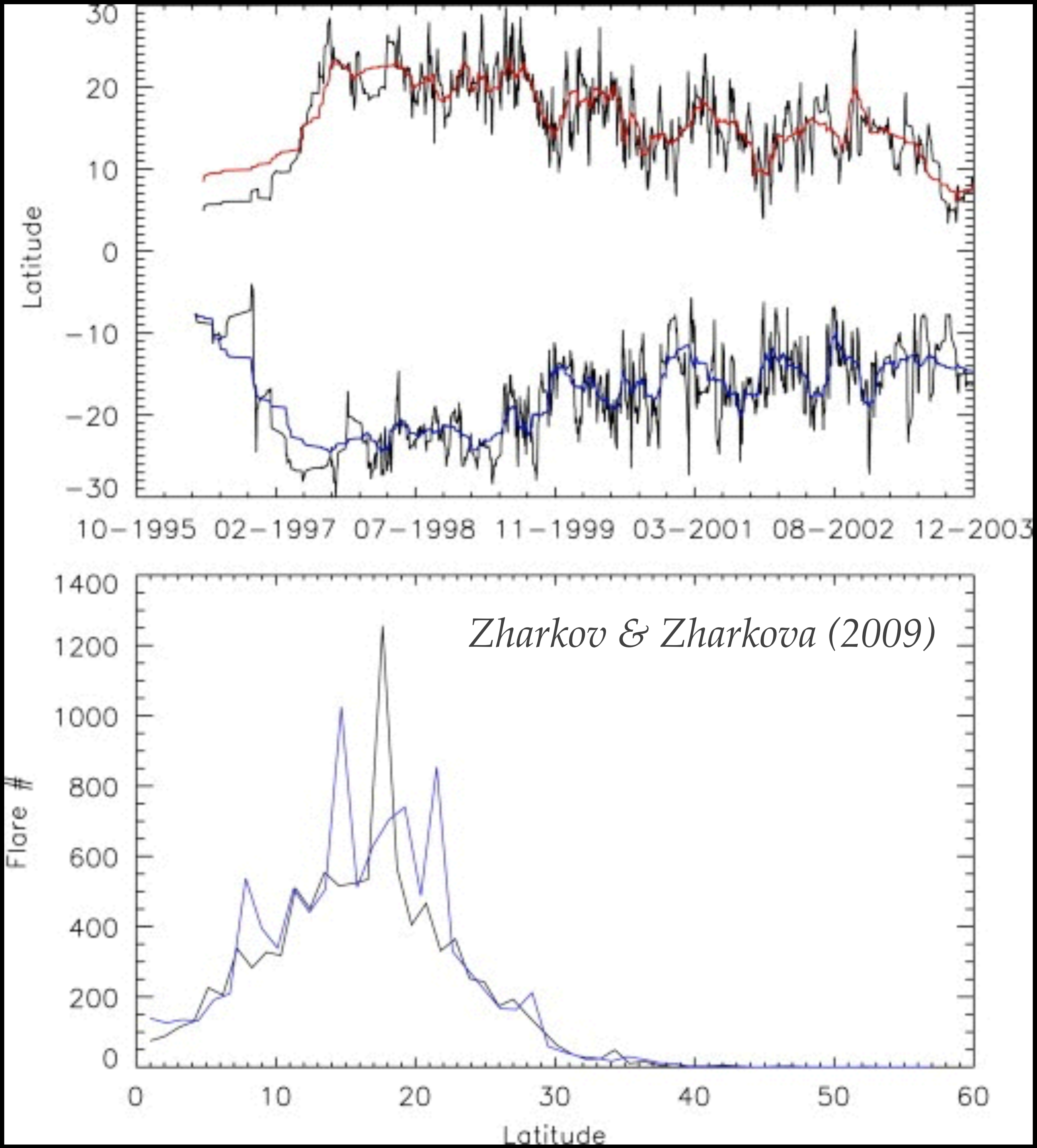

Virtually all active regions show sub-flaring activity (event class < C). However, not all active regions host major flares.

MAJOR FLARE SIGNIFICANCE & FREQUENCY

- Solar flares are relaxation events. However, by themselves they are not sufficient to return the host active region to its ground, "potential" energy state (due to magnetic helicity).

- Solar flares, no matter how large, release only a relatively small (~ 10% max) fraction of the available free energy

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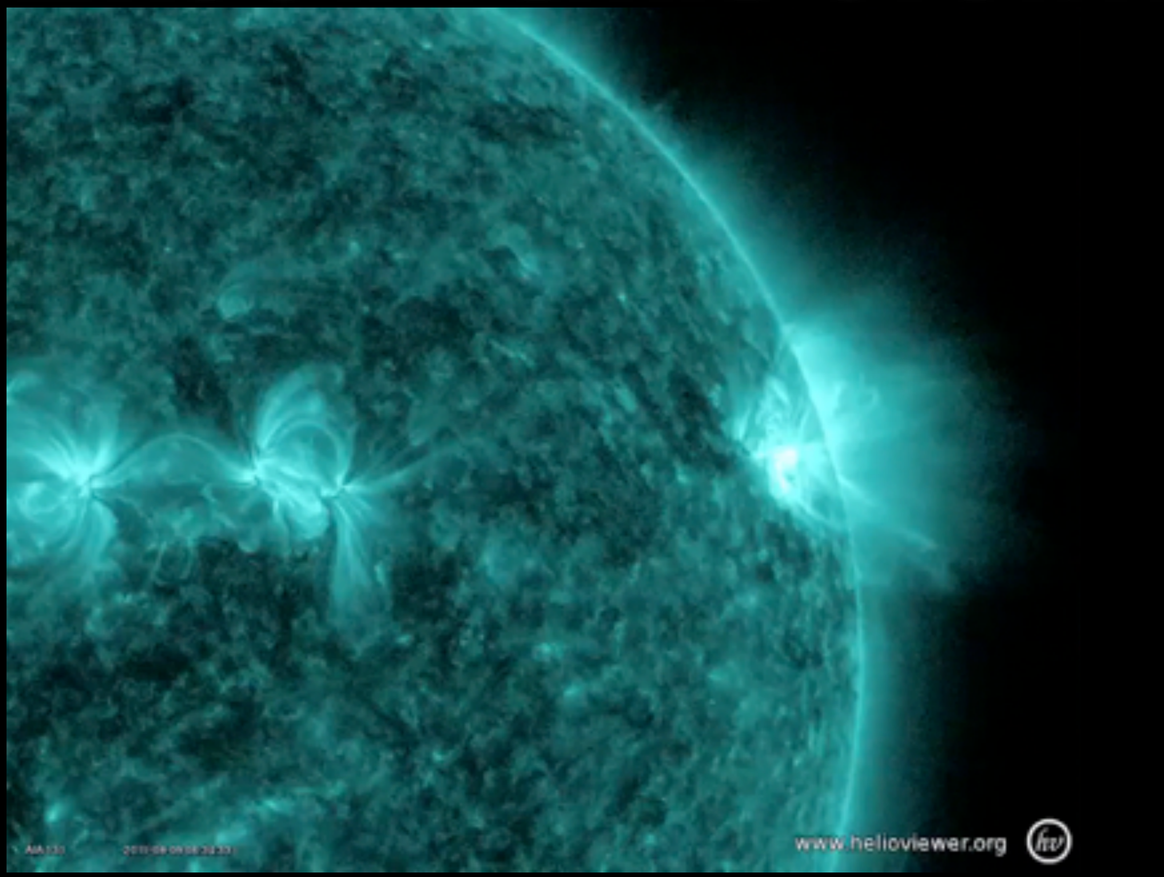

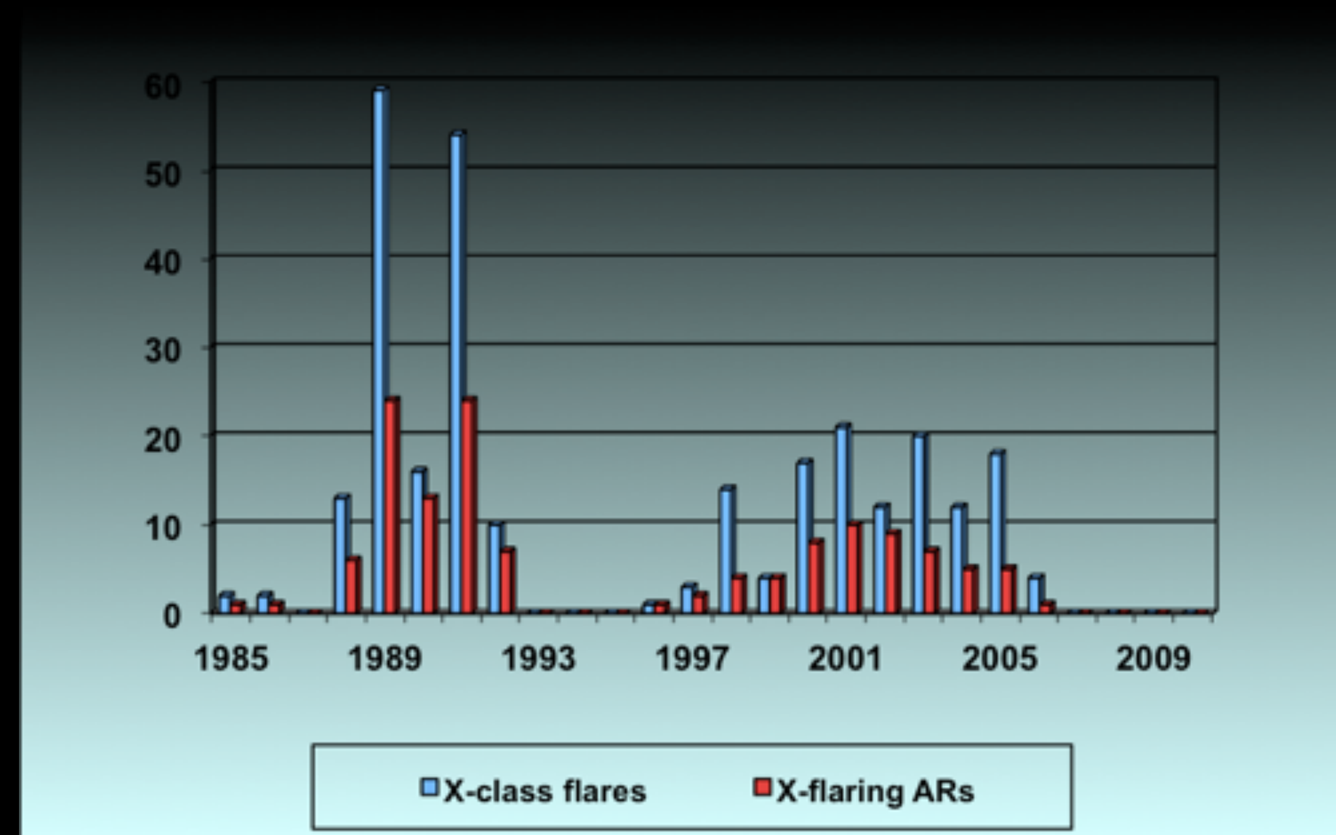

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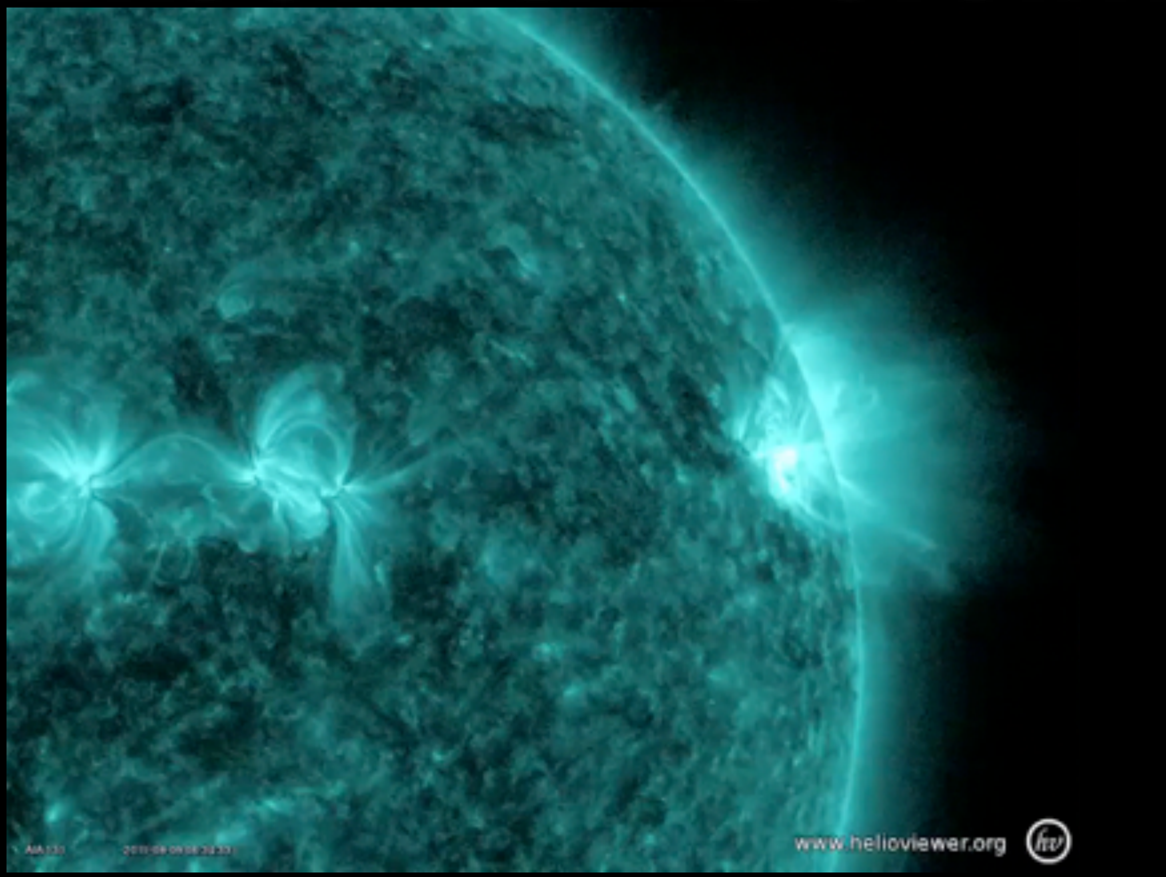

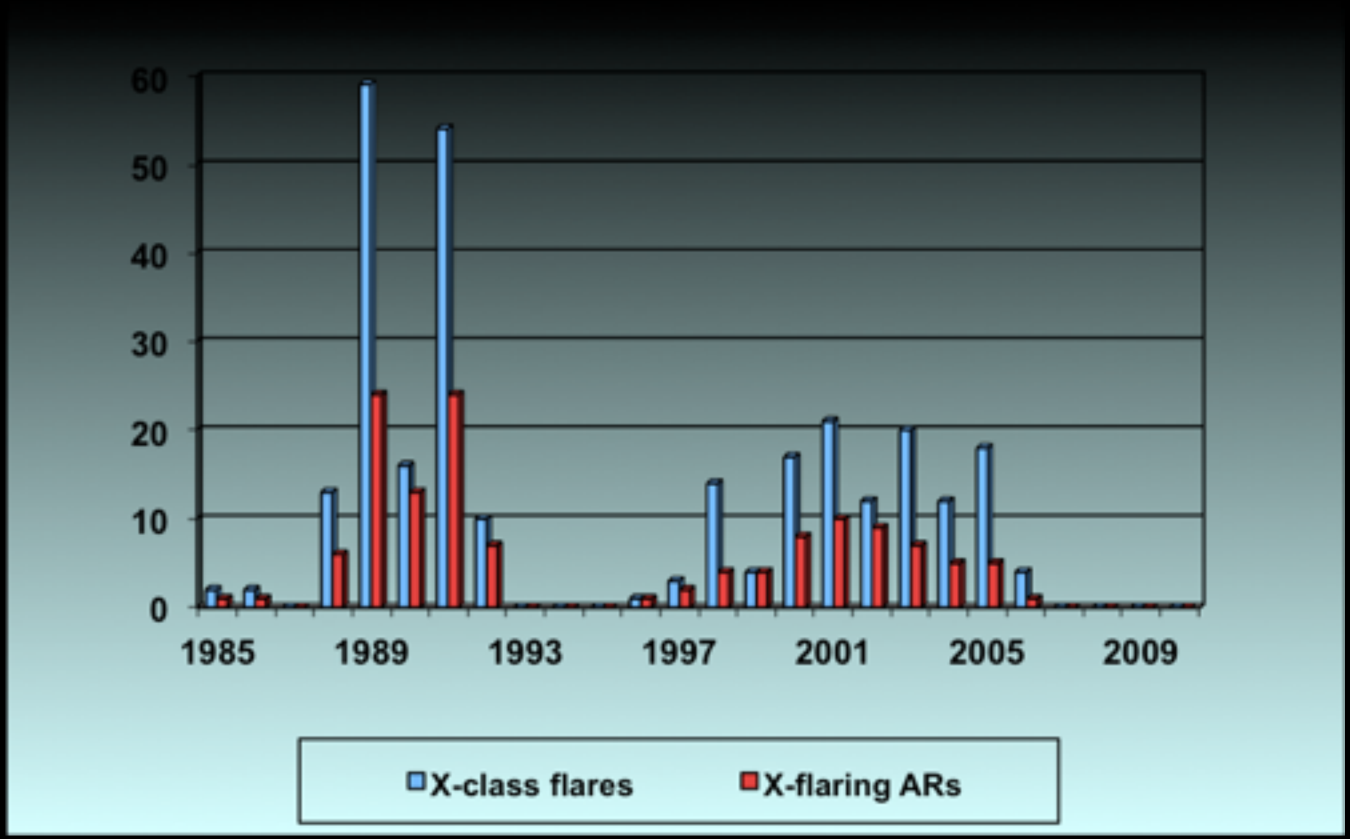

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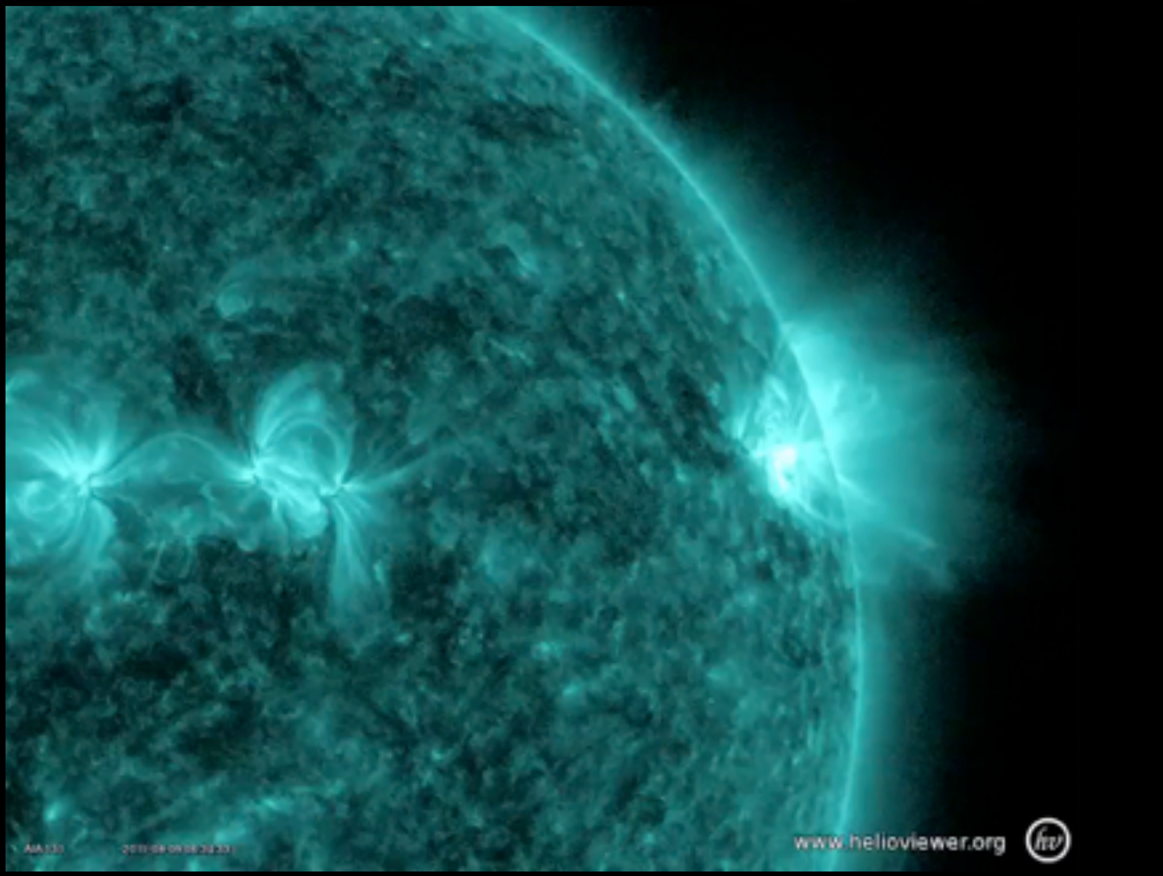

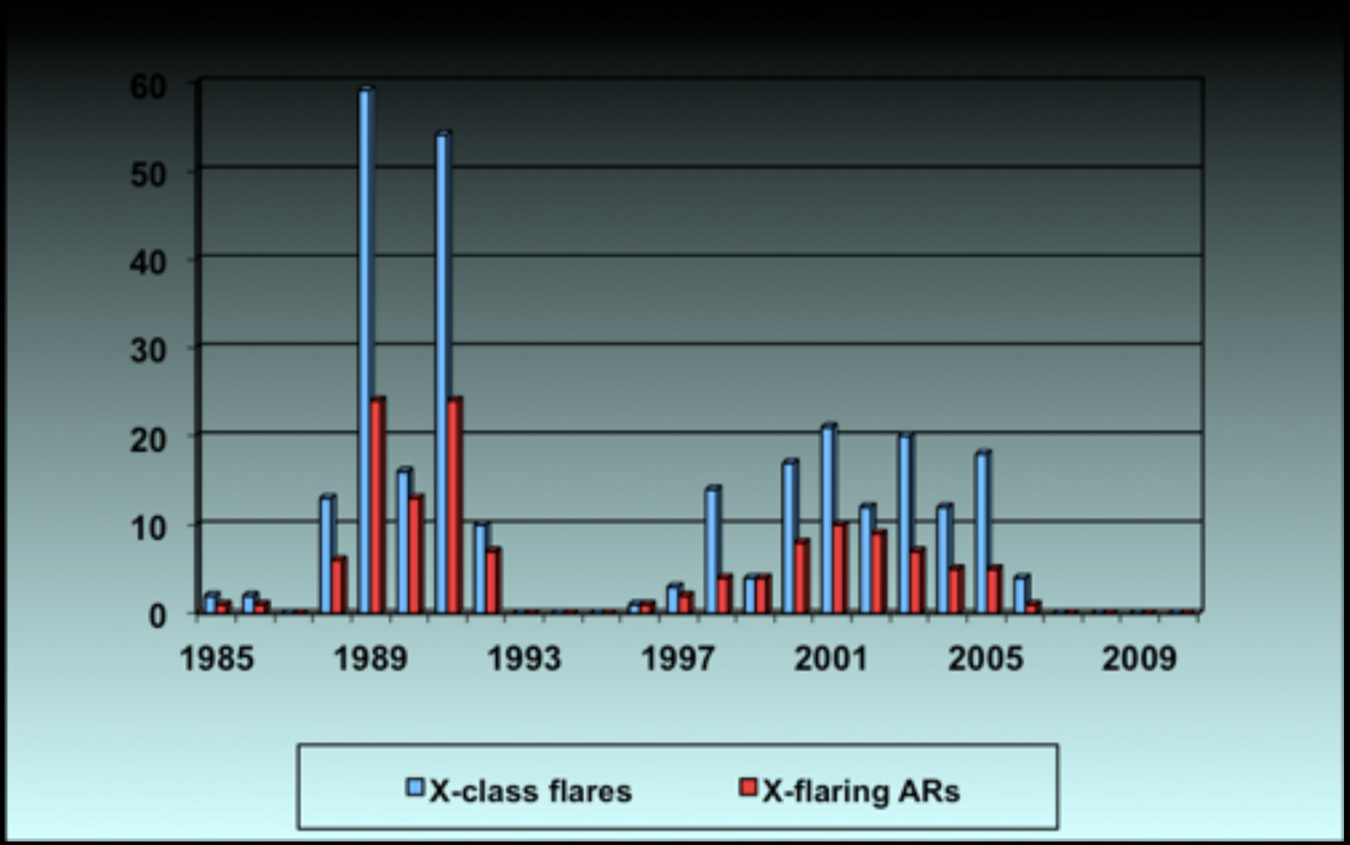

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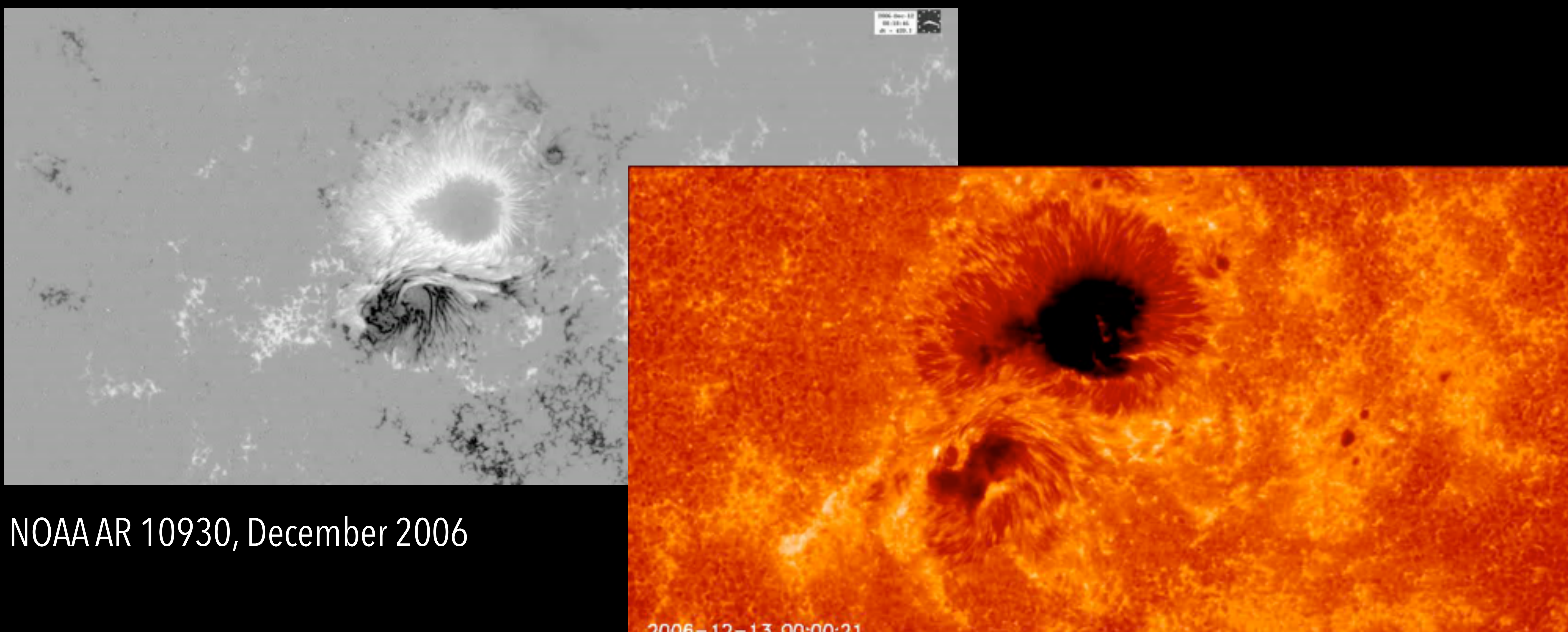
Less that 2% of active regions will ever give an X-class flare!

FLARING ACTIVE REGIONS

There are basically <u>two types</u> of active regions giving major flares (some flaring regions show both characteristics):

- Regions with intense photospheric magnetic polarity inversion lines:

Sufficient (not necessary) condition, but for a finite interval!



NOAA AR 10930, December 2006

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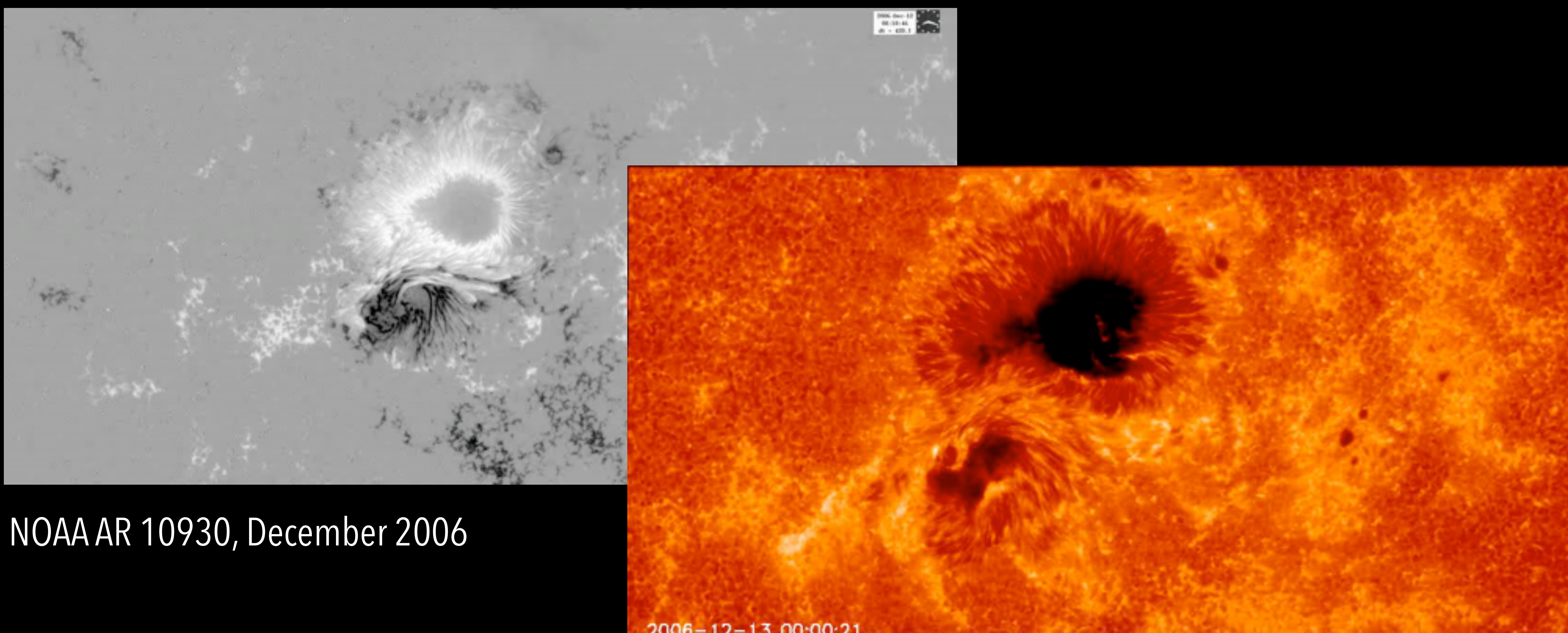

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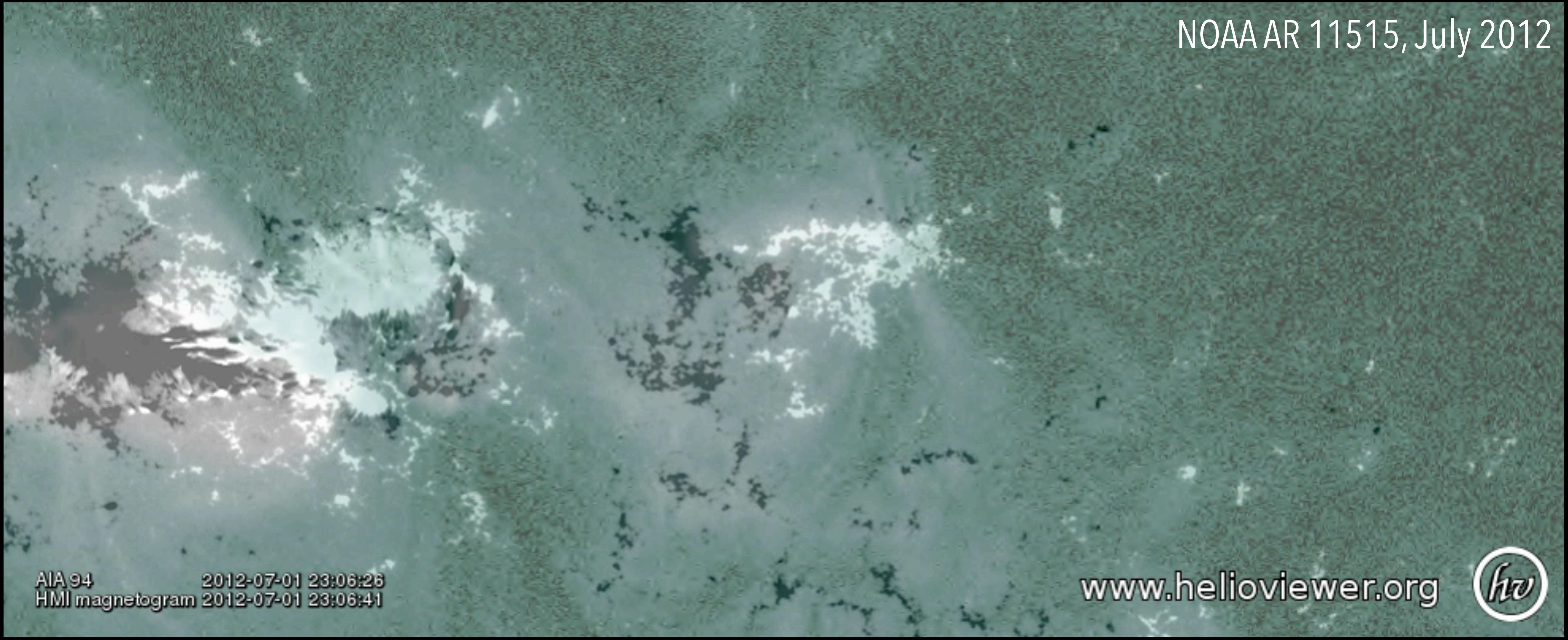

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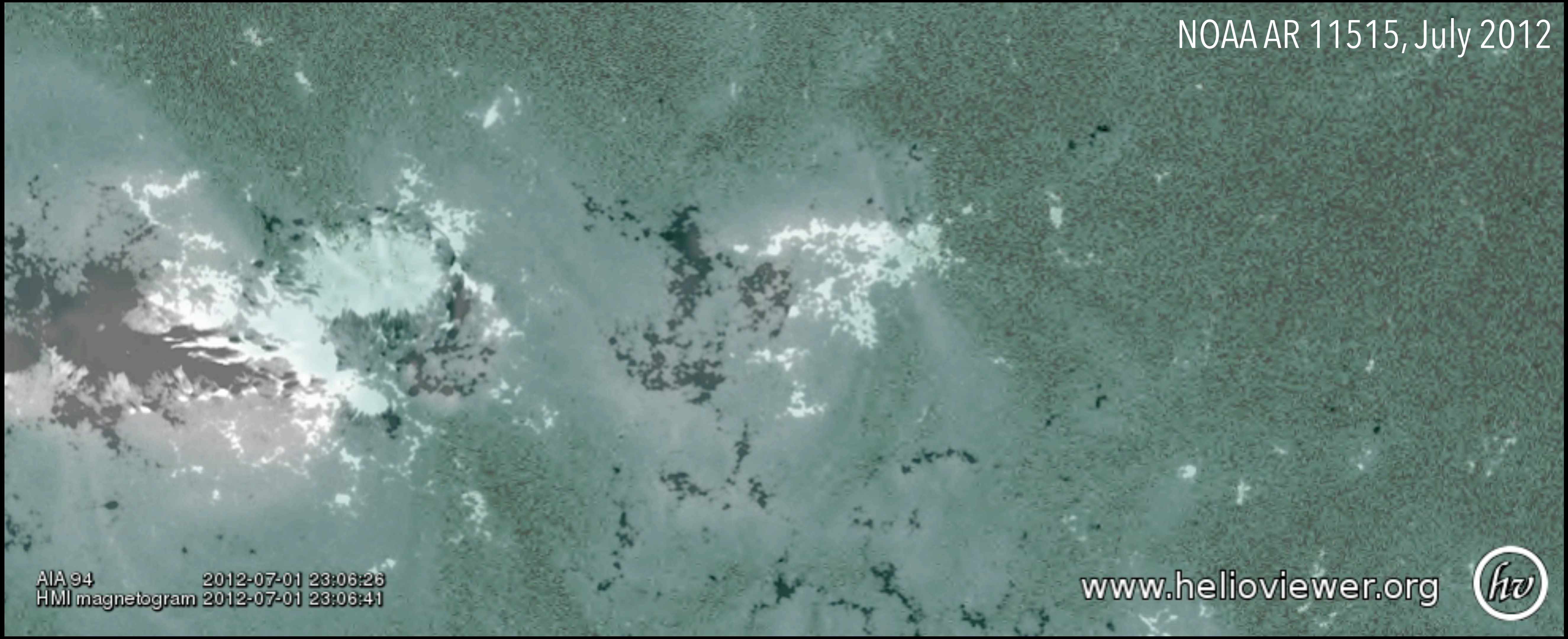

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Georgoulis (Astroph. Space Sci. Proc., 2012), for more information

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- Other (slightly exotic) methods — Jenkins & Fischbach (2009); Javorsek et al. (2012); Strugarek & Charbonneau (2014)

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WHAT HAVE WE GAINED?

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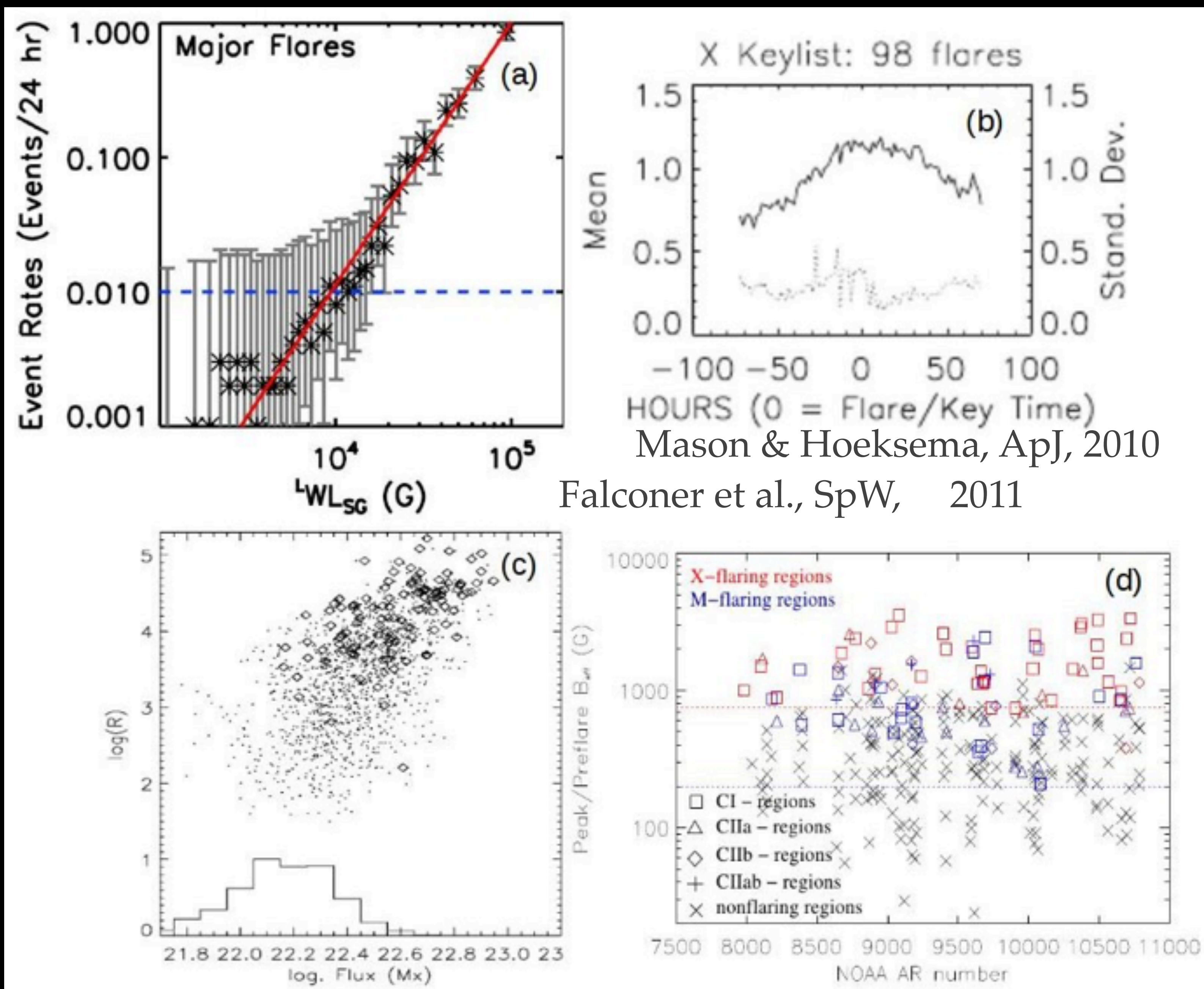
(Highly subjective opinion): well, not much! If we have learned anything, then this is that morphological methods seem to offer the biggest promise (*see also Georgoulis [2012, SoPh]*)

WHAT HAVE WE GAINED?

Vendor	Country	Prediction Method	Remarks	Categorization
NOAA Space Weather Prediction Center (SWPC)	USA	Traditional look-up tables - Mount Wilson Sunspot Classification	1. Continuum obs. 2. Not-automatic, "expert-based"	"Eyeball" morphological
Solar Monitor / Max Millennium Project	USA - Ireland	McIntosh Sunspot Classification	1. Continuum obs. 2. Non-automatic, "expert-based"	"Eyeball" morphological
Automated Solar Activity Prediction (ASAP)	UK	Machine Learning / Artificial Intelligence	1. Continuum & magnetogram obs. 2. **Automated**	Machine-learning
NASA Space Radiation Analysis Group (SRAG)	USA	Properties of photospheric PILs	1. Magnetogram obs. 2. **Automated**	Morphological
SOTERIA Flare Predictor Tool	BE	McIntosh Sunspot Classification	Essentially relying on Solar Monitor	"Eyeball" morphological

FLARE-PREDICTIVE PROBABILITIES

Predictive power based on the ability of parameters to <u>segregate</u> between flaring and non-flaring active regions for given latency, flare class, and forecast window



Mason & Hoeksema, ApJ, 2010

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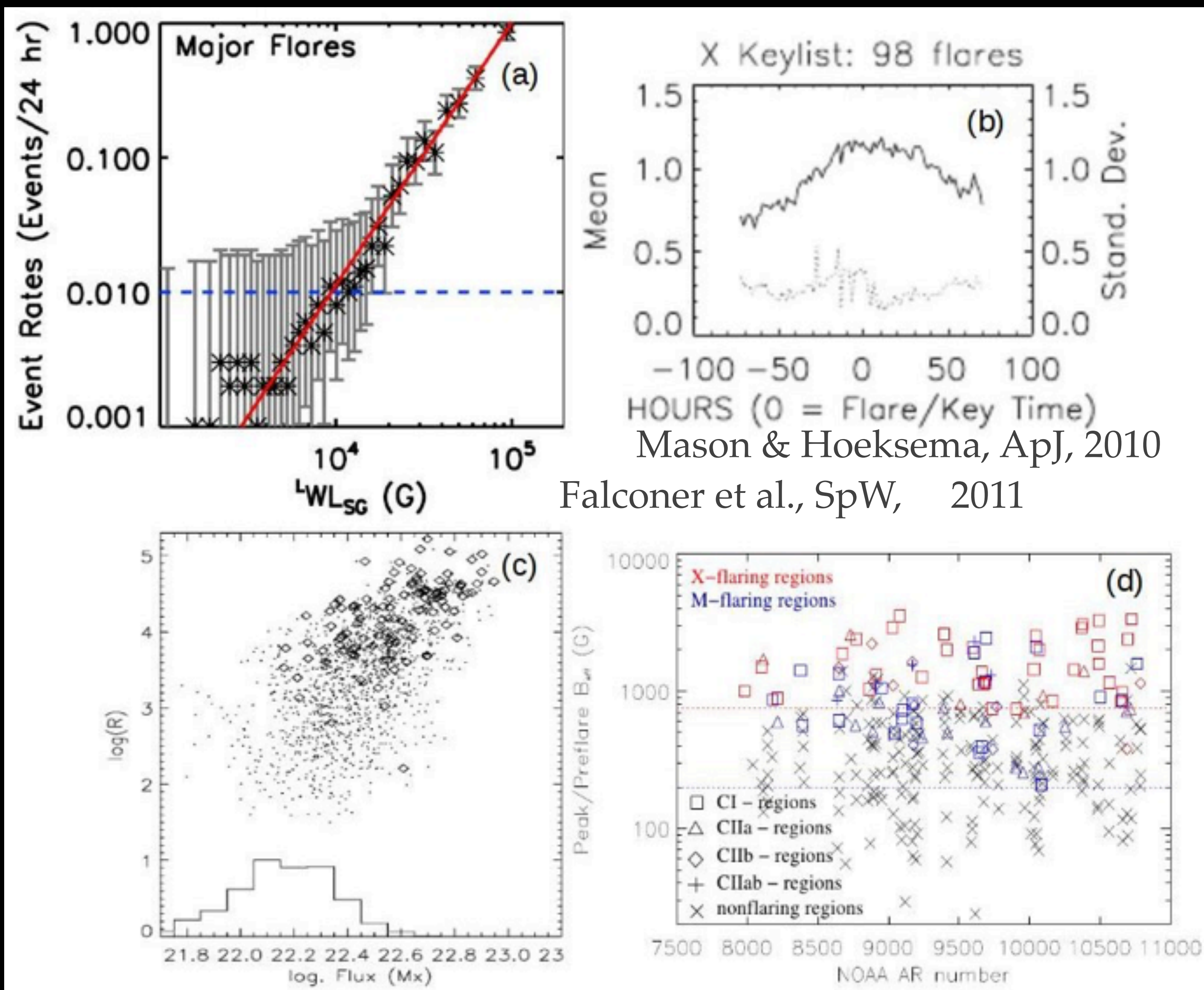

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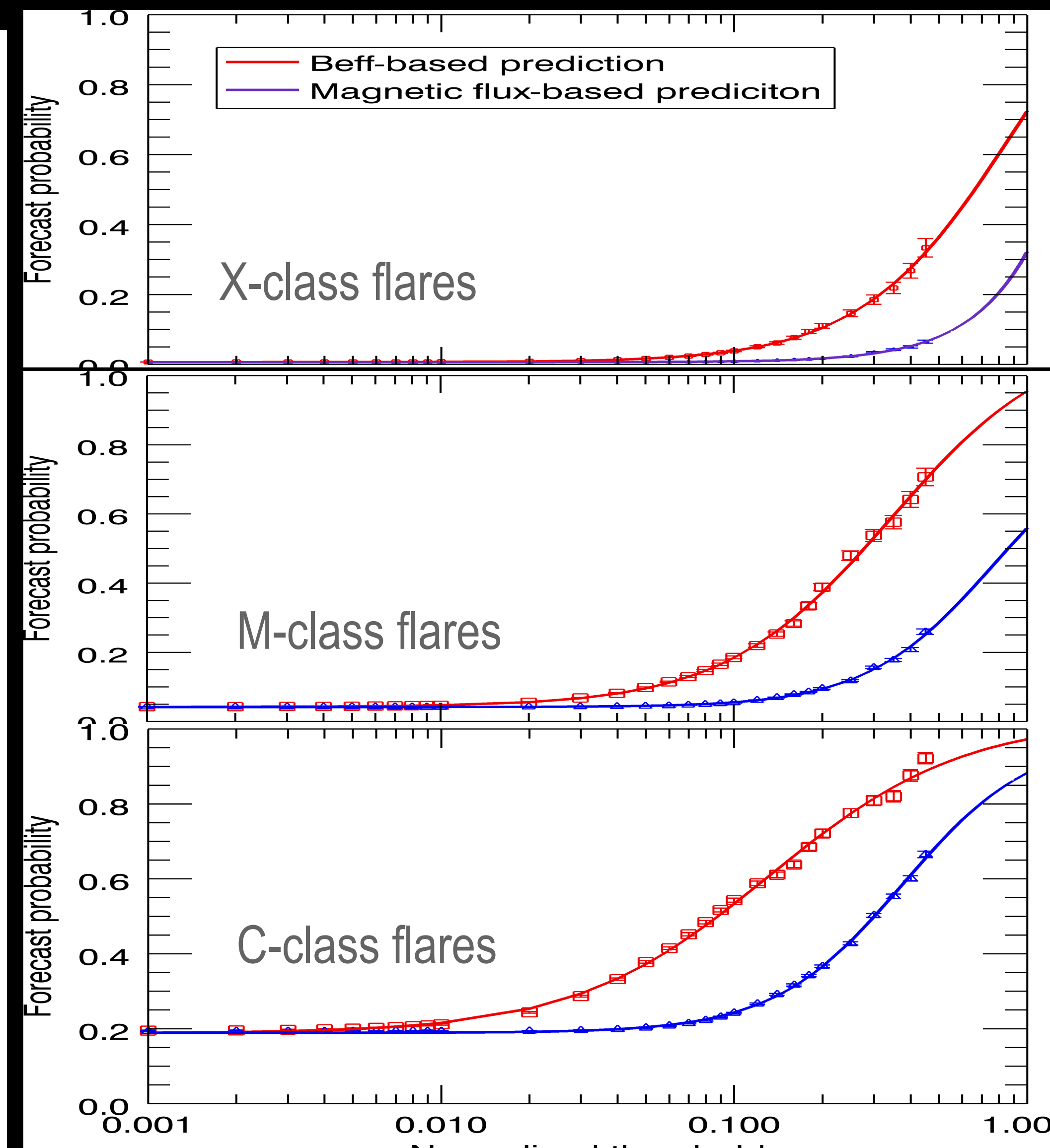
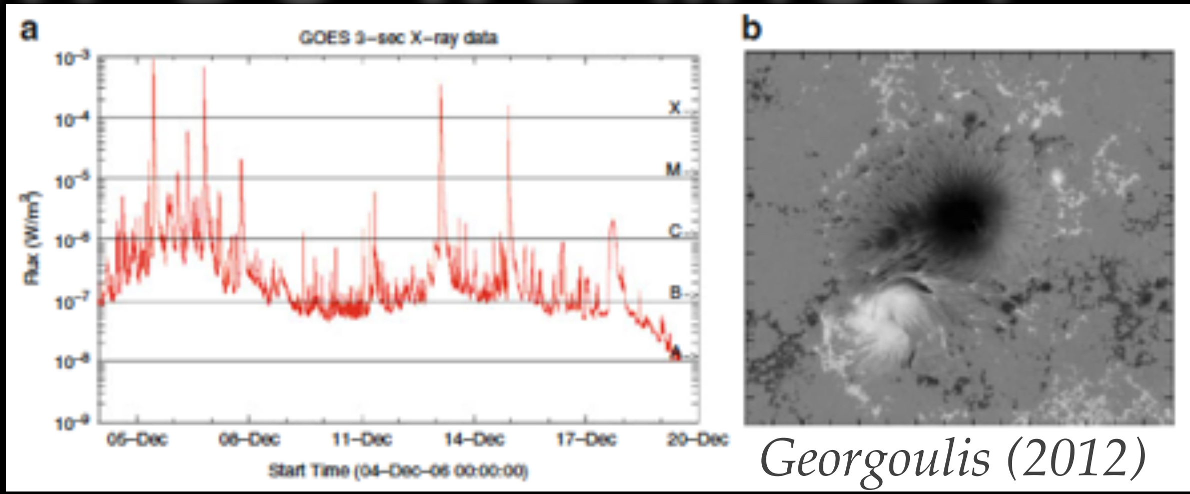


Example: sigmoidal curve fitting (other ways exist)

SHORTCOMINGS: WHAT DO WE MISS?

- Flares are processes involving stochasticity. Probabilistic prediction only!



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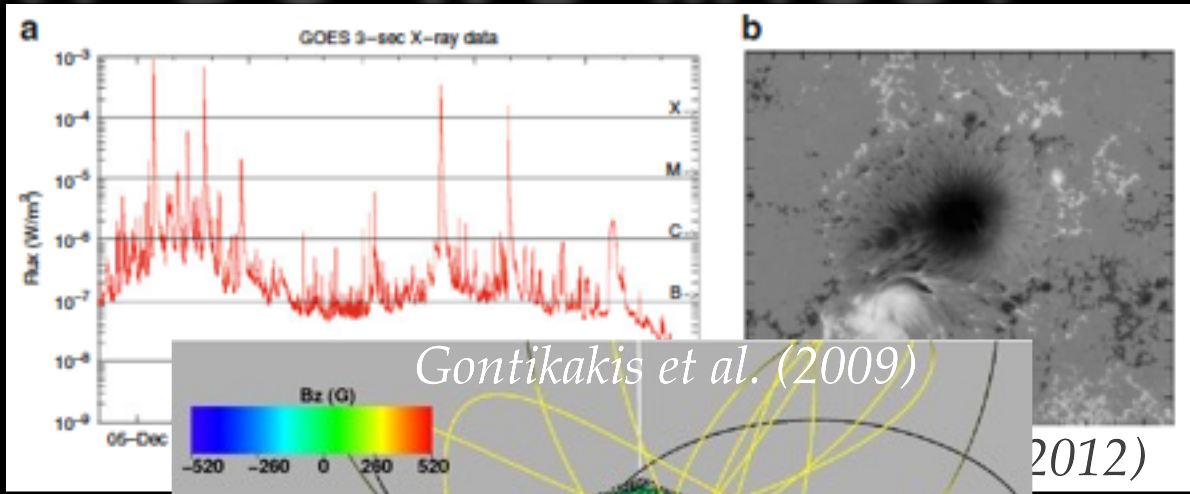

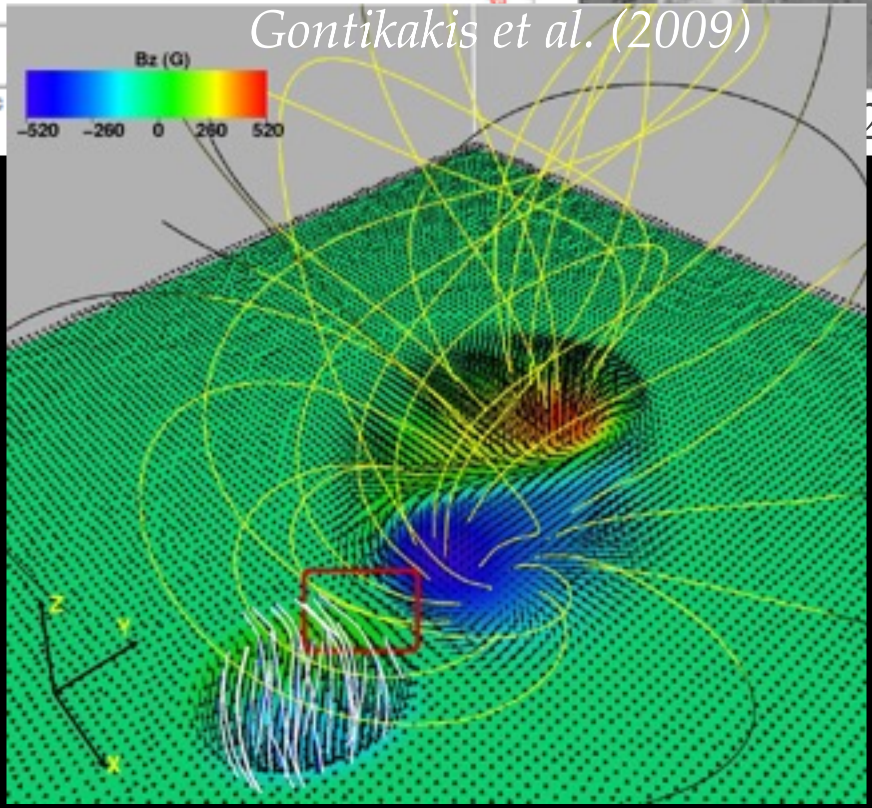

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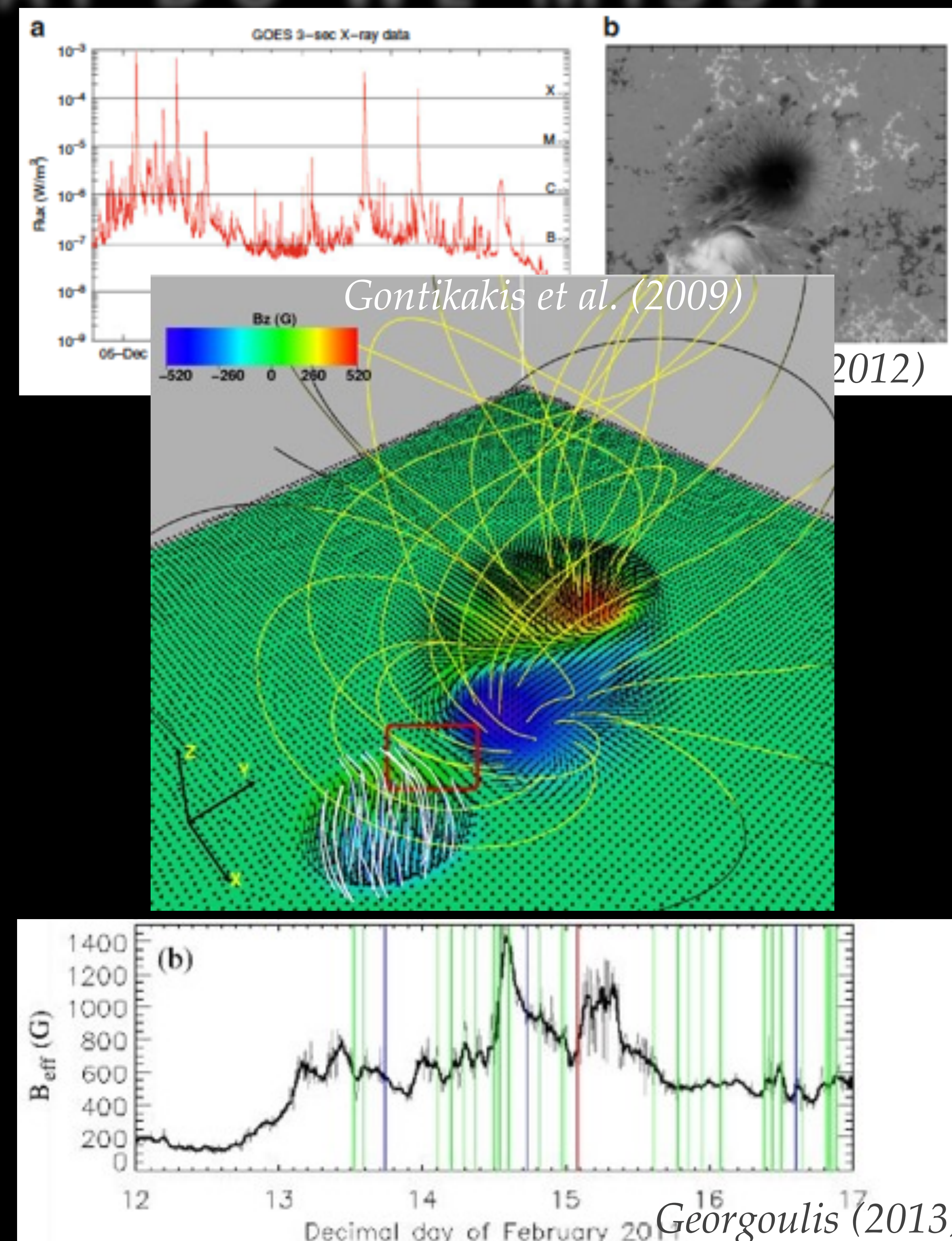
- Timeseries of flare-predictive parameters may play an as important role as their instantaneous values!



Gontikakis et al. (2009)

2012)

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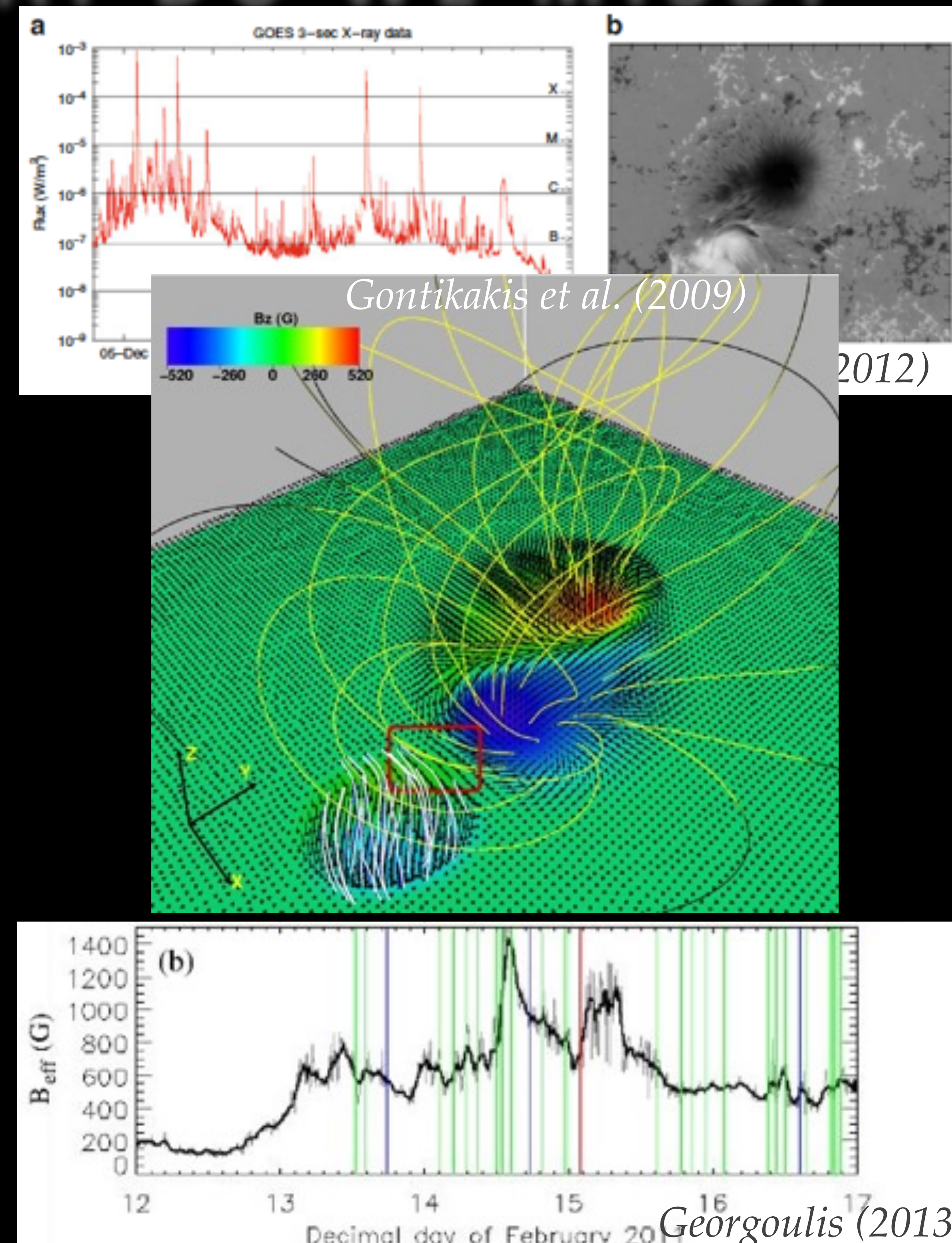
- Possible precursors - where / what are they, if they exist?



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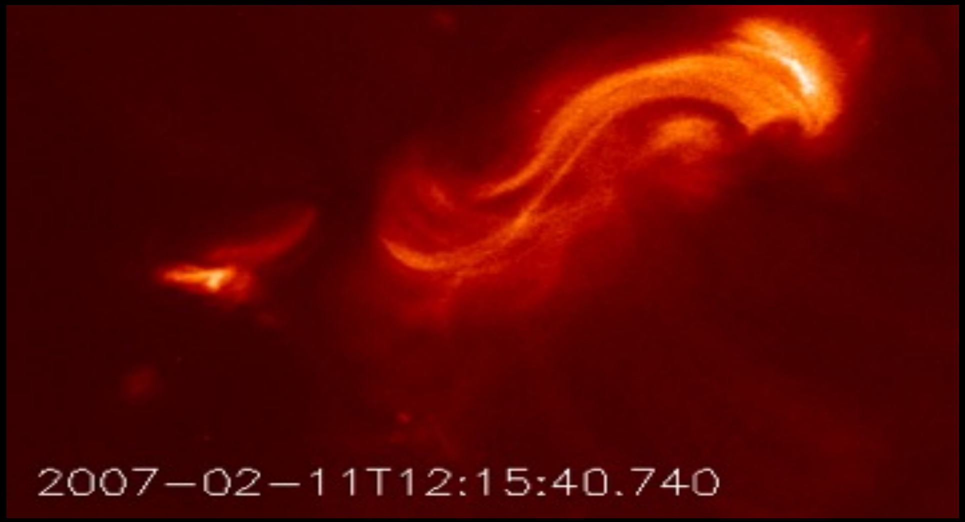

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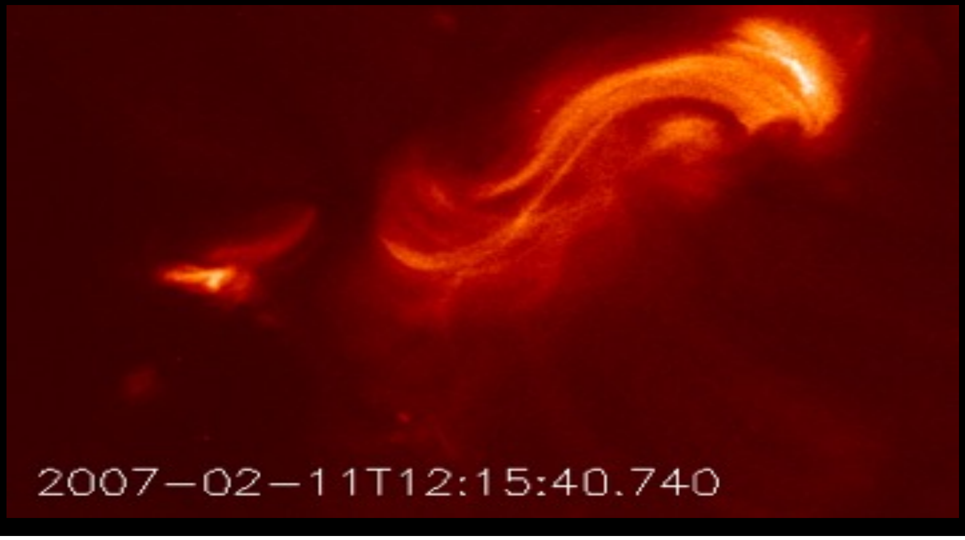

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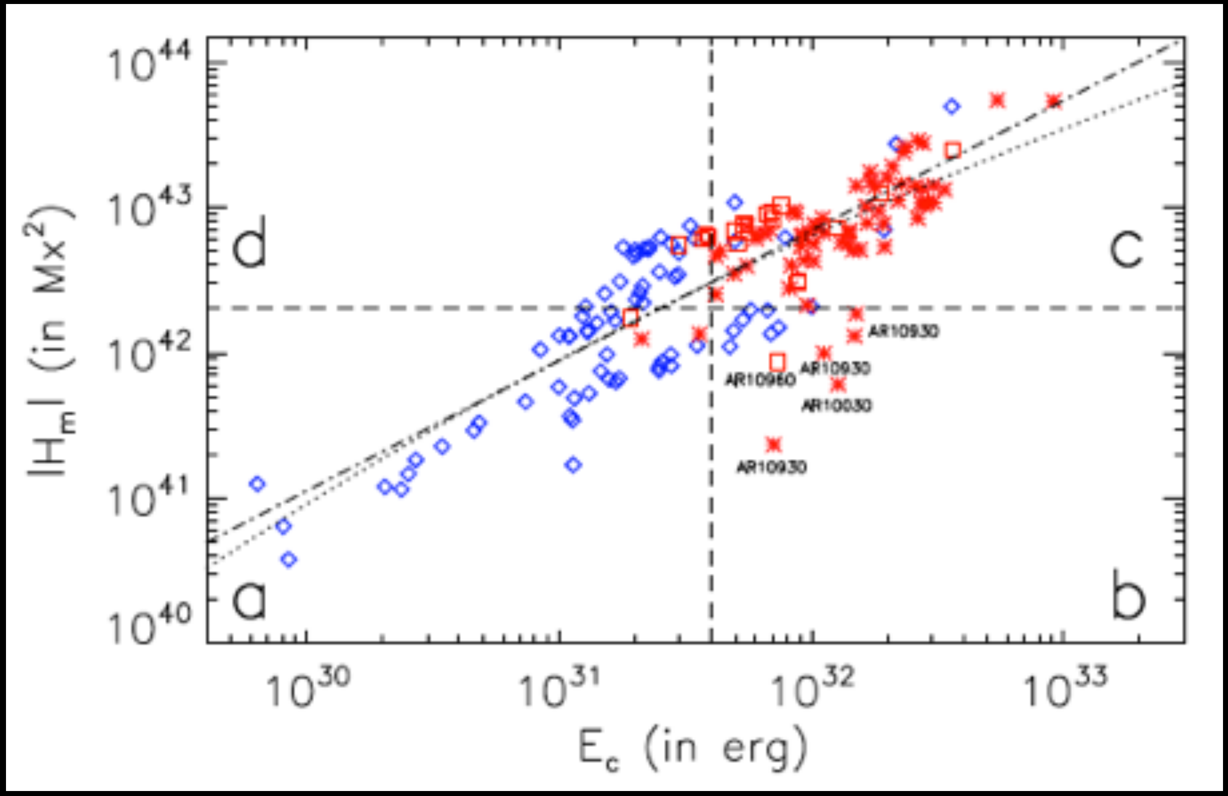

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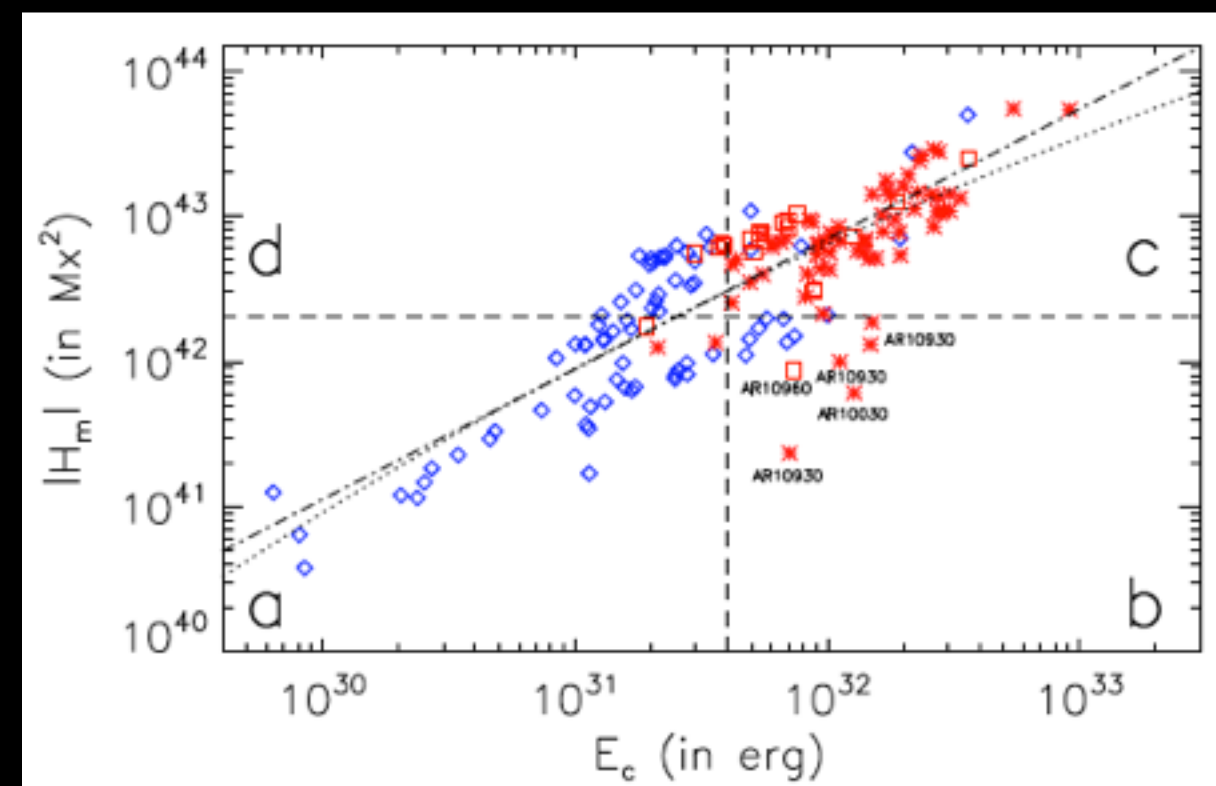

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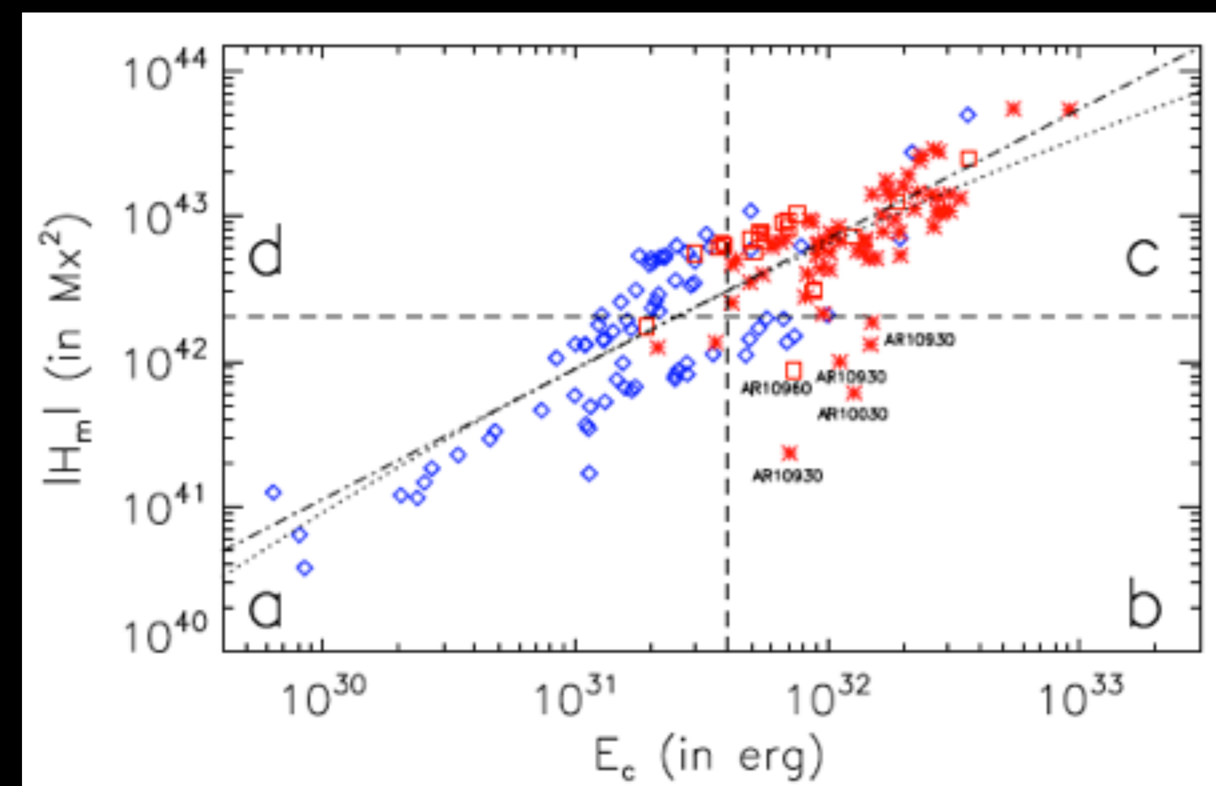

- Precise calculations of the coronal magnetic free energy and helicity in active regions
- Better (physical/statistical) understanding of the temporal evolution of flare-predictive parameters
- Optimal validation practices

Yesterday's talk *Solar Metrics and Tools* Splinter

CONCLUSION

- Solar flares (excluding subflares) are almost exclusive phenomena of active regions, under very specific circumstances (PILs, intense flow/flux emergence areas)
- A relatively small fraction of the community has even tackled solar flare prediction. The output, however, is impressive in terms of methods proposed and (often strong) opinions
- Results are still sketchy and this can be attributed (i) to the lack of concerted efforts with concrete, homogeneous output over different methods and (ii) the lack of coordinated validation / performance verification efforts
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Overall, a formidable but exciting problem. Meaningful developments - when achieved - will be groundbreaking!