

The logo for FLARECAST, featuring the word "FLARECAST" in white capital letters on a red background that resembles a stylized sun or flame.

European  
Commission

Horizon 2020  
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# Solar Magnetic Data Analysis for the FLARECAST project

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Irish National Astronomy Meeting (INAM), UCD, Sept. 7 – 9 2016

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# The FLARECAST Project

- Flare Likelihood And Region Eruption foreCASTing:  
EC H2020 consortium project.



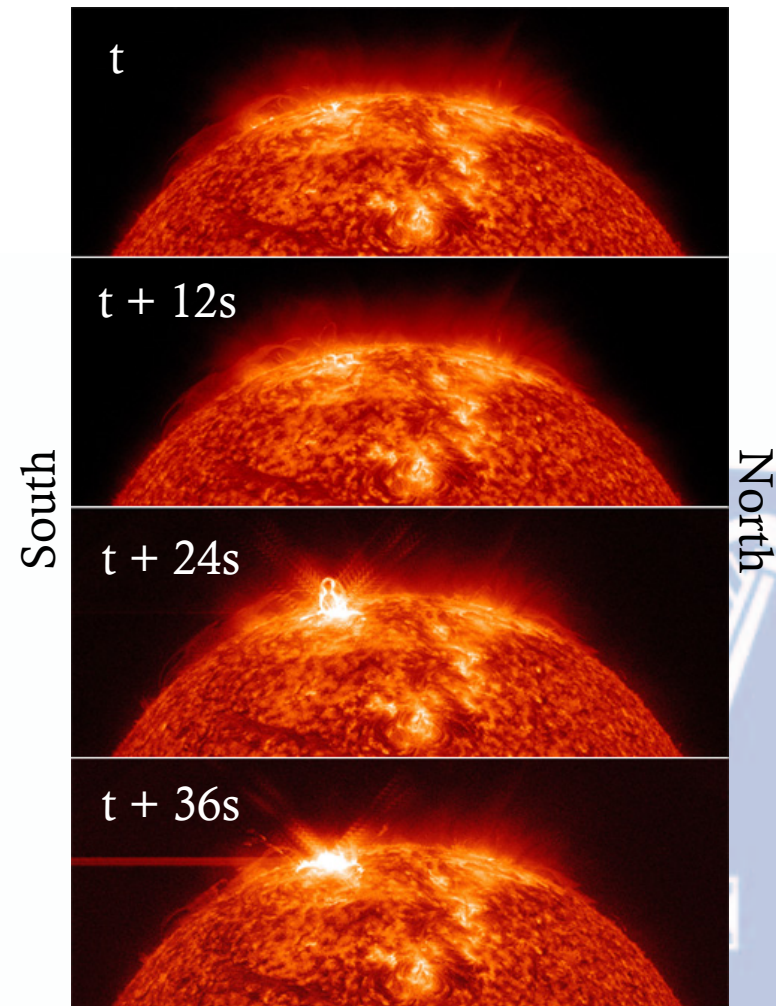
## Goals:

- Understanding properties and evolution that leads to flares.
- Enhance quality of flare predictions by using a great number of predictors and state-of-the-art prediction algorithms.
- Allow end-users access to past and future data for scientific and operational purposes.



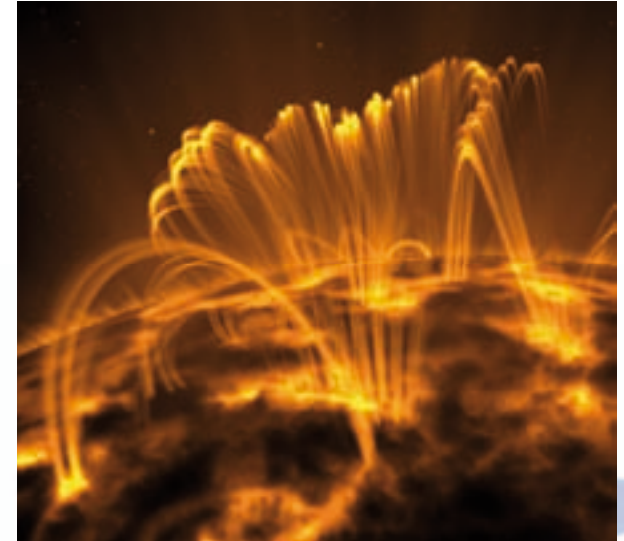
# Solar Flares

- Rapid enhancement of emission.

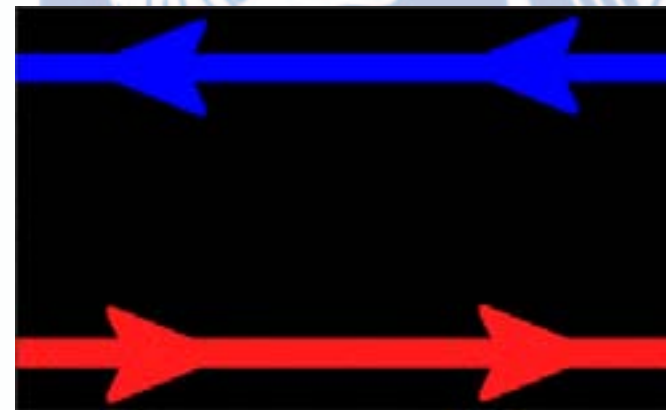


# Solar Flares

- Rapid enhancement of emission.
- EM nature: energy released via magnetic reconnection of **B** lines.



Coronal loops



Reconnection of field lines

# Solar Flares

- Rapid enhancement of emission.
- EM nature: energy released via magnetic reconnection of **B** lines.
- Origin in strong-**B** areas in the Sun's surface (active regions)

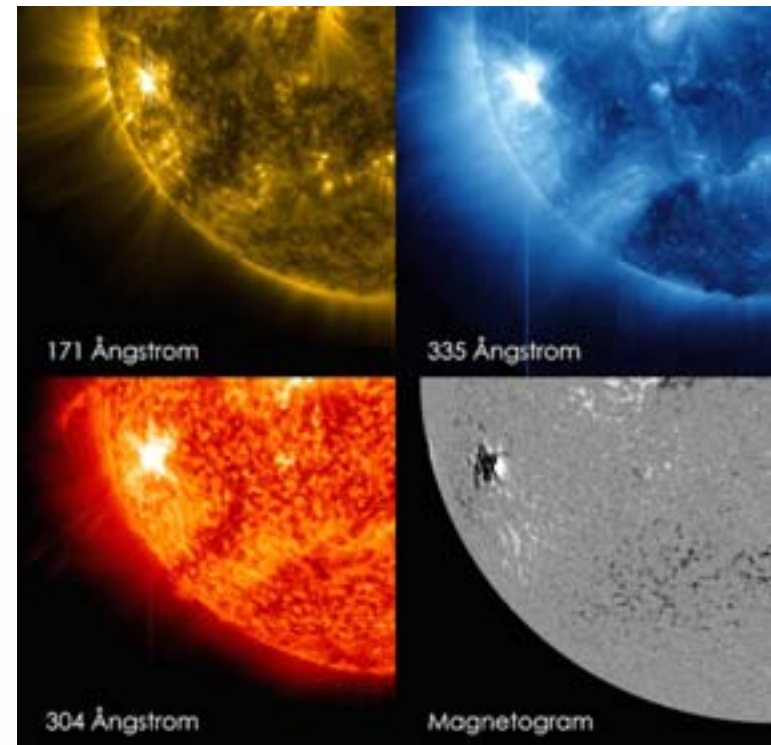
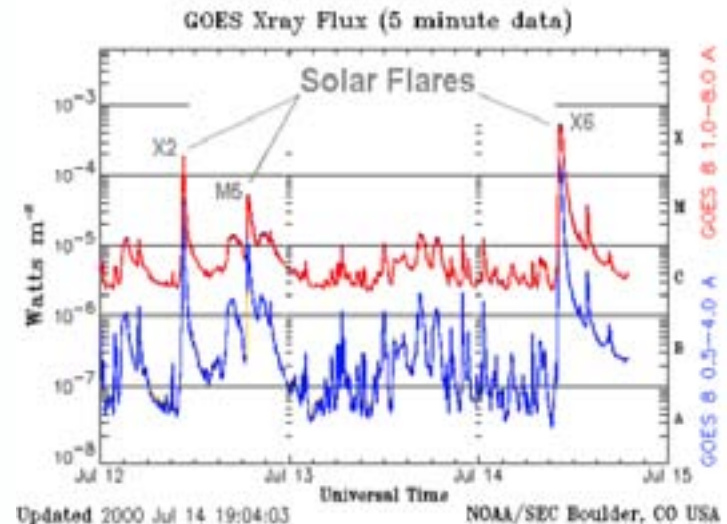


Image: SDO HMI (surf. magnetic)  
and AIA (EUV coronal)



# Solar Flares

- Rapid enhancement of emission.
- EM nature: energy released via magnetic reconnection of **B** lines.
- Origin in strong-**B** areas in the Sun's surface (active regions)
- Classified according to peak in X-rays near Earth.



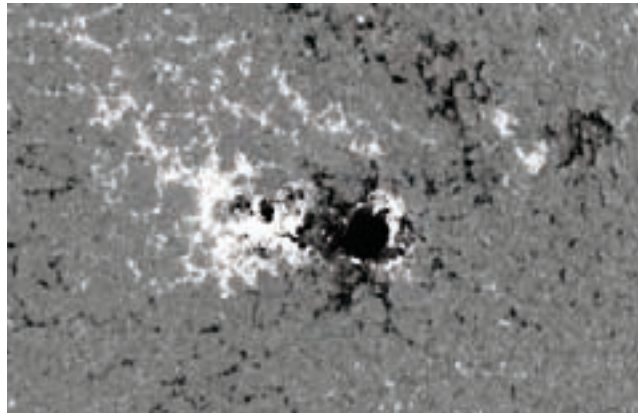
Data: GOES X-rays

# Photospheric predictors of Solar Flares

- Search for patterns in the Sun's photosphere and empirical relations.



Magnetic Field  
or  
Magnetogram

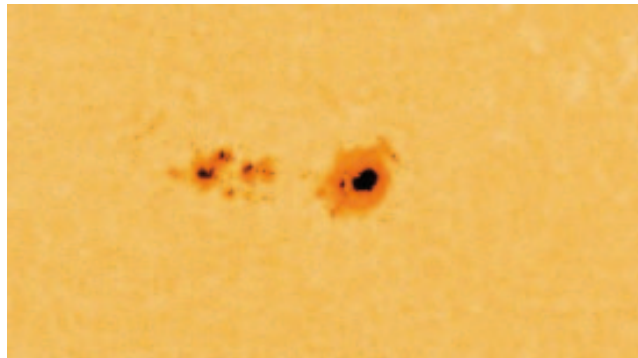


Magnetic class (Bornmann & Shaw, 1994)

Length of Polarity Inversion  
Line (PIL, Falconer 2003)

Total magnetic flux

Visible surface



McIntosh class (1990)

Sunspot group area (Qahwaji  
& Colak, 2008)

# Work Package 2: Active regions properties

- TCD focuses on the satellite data analysis for extracting AR properties (WP2).
- These properties will be used by the prediction algorithms.
- Calculate as many as possible (relevant) parameters.



## Property Extraction Algorithms

LOS magnetograms	
	SMART-derived properties (Ahmed et al., 2013)
	SMART delta finder (Padinhalteeri et al., 2015)
→	Effective connected magnetic field strength ( $B_{\text{eff}}$ ) (Georgoulis & Rust, 2007)
	Fractal dimension (Georgoulis, 2012)
	Multi-fractal structure function $s(q)$ inertial range index $k$ (Georgoulis, 2012)
→	Fourier power spectral index (Guerra et al., 2015)
	CWT power spectral index (Hewett et al., 2008)
	Generalised correlation dimension (Georgoulis, 2012)
	Holder exponent $h$ (Conlon et al., 2010)
	Hausdorff dimension $D(h)$ (Conlon et al., 2010)
	WTMM (Conlon et al., 2010)
→	Decay index (Zuccarello et al. 2014)
→	Magnetic polarity inversion line characteristics (Mason & Hoeksema 2010)
	3D magnetic null point (Reid et al. 2012)
→	$R$ (Schrijver 2007) *
	$L_{\text{WL-SG}}$ (Falconer et al. 2008) *
→	Ising energy (Ahmed et al. 2010)
	$WG_M$ and $S_{1,T}$ (Korsos et al. 2015)
	Magnetic helicity injection rate proxy (Park et al. 2010)





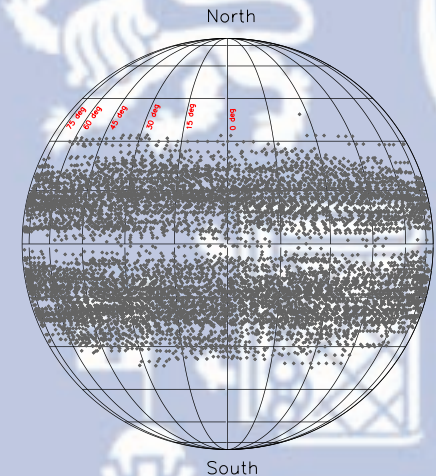
# Spaceweather HMI Active Region Patches

- ?**

A circular visualization of a hierarchical clustering dendrogram. The main structure is a large circle containing a dendrogram with several clusters highlighted in different colors: red, green, blue, purple, and yellow. Each cluster is accompanied by a zoomed-in inset showing the internal structure of that cluster. The clusters are labeled with IDs such as 110004, 110005, 110006, 110007, 110008, 110009, 110010, 110011, 110012, 110013, 110014, 110015, 110016, 110017, 110018, 110019, 110020, 110021, 110022, 110023, 110024, 110025, 110026, 110027, 110028, 110029, 110030, 110031, 110032, 110033, 110034, 110035, 110036, 110037, 110038, 110039, 110040, 110041, 110042, 110043, 110044, 110045, 110046, 110047, 110048, 110049, 110050, 110051, 110052, 110053, 110054, 110055, 110056, 110057, 110058, 110059, 110060, 110061, 110062, 110063, 110064, 110065, 110066, 110067, 110068, 110069, 110070, 110071, 110072, 110073, 110074, 110075, 110076, 110077, 110078, 110079, 110080, 110081, 110082, 110083, 110084, 110085, 110086, 110087, 110088, 110089, 110090, 110091, 110092, 110093, 110094, 110095, 110096, 110097, 110098, 110099, 110100. The clusters are connected by lines representing the distance between them. The visualization is set against a light gray background with a black 'X' at the bottom center.

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# Active region properties

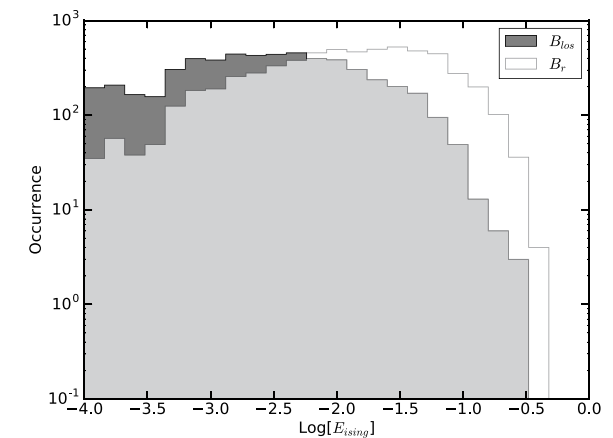
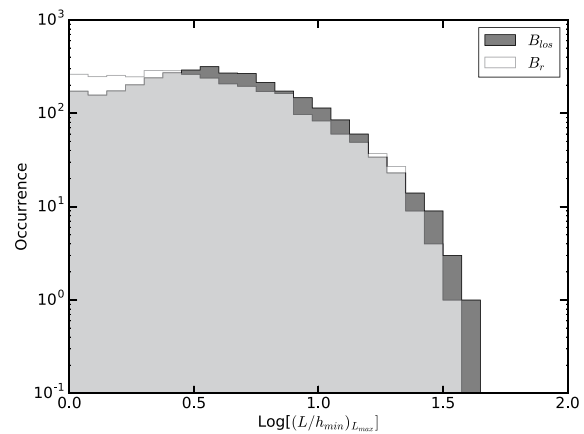
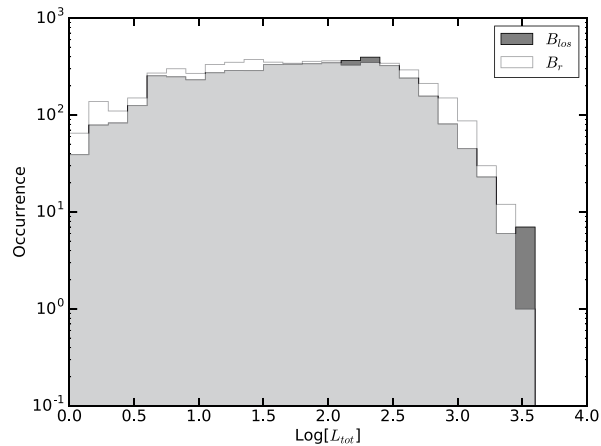
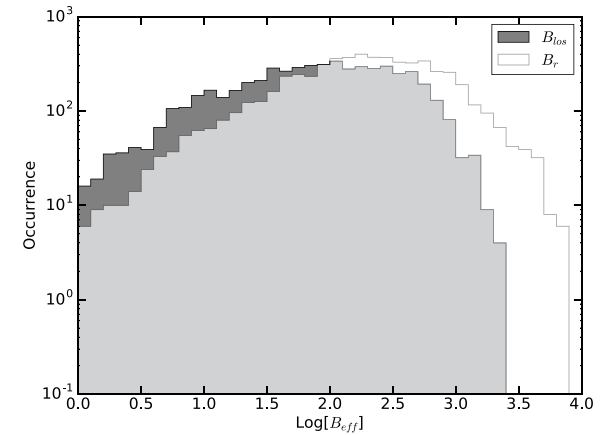
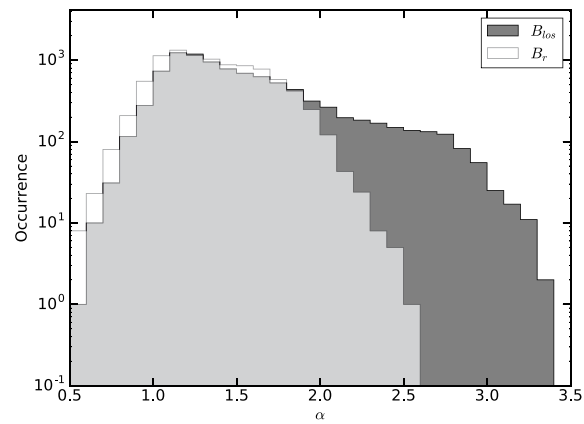
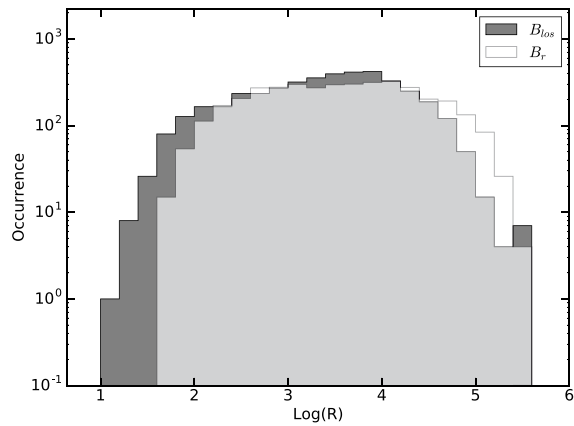
- Active region properties considered:
  - Schrijver's R value (Flux PILs)
  - Fourier spectral index,  $\alpha$  (Scaling of spectral power)
  - MPIL-related properties (Total length of PILs)
  - Decay index (Vert. variation of potential field)
  - Effective connected Field strength (coronal connectivity)
  - Ising energy (coronal connectivity)
- Special emphasis on differences when using  $B_{los}$  and  $B_r$ .





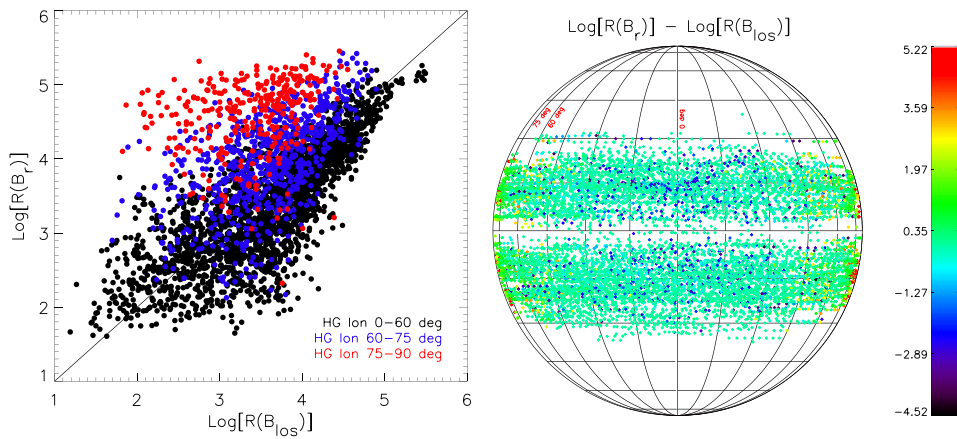
# Preliminary results

At 6 h cadence: 12733 regions. Valid points: 9454



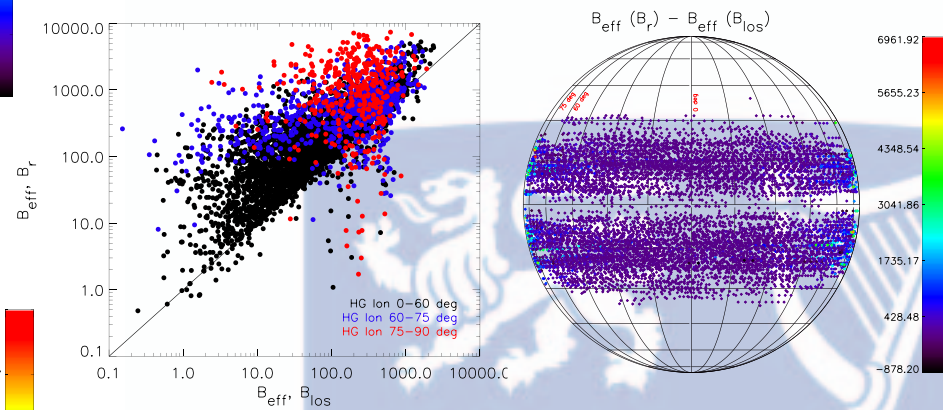
# Preliminary results

- Log(R)

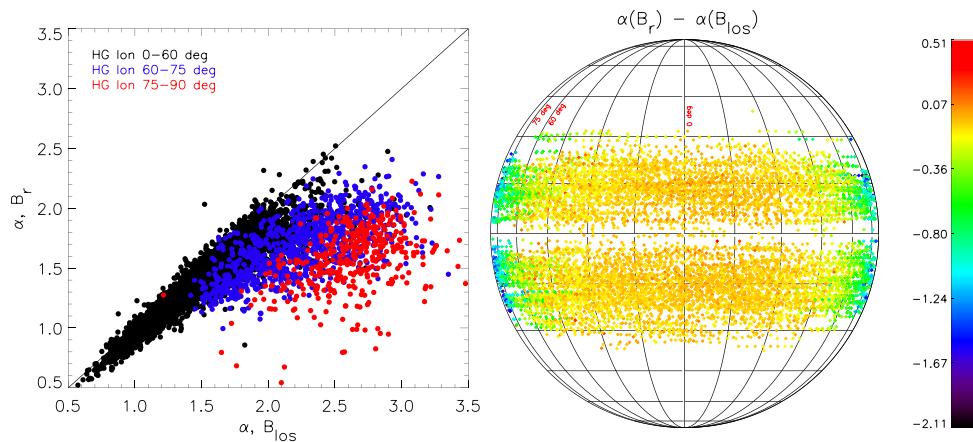


## Variation with AR longitudinal position

- $B_{\text{eff}}$



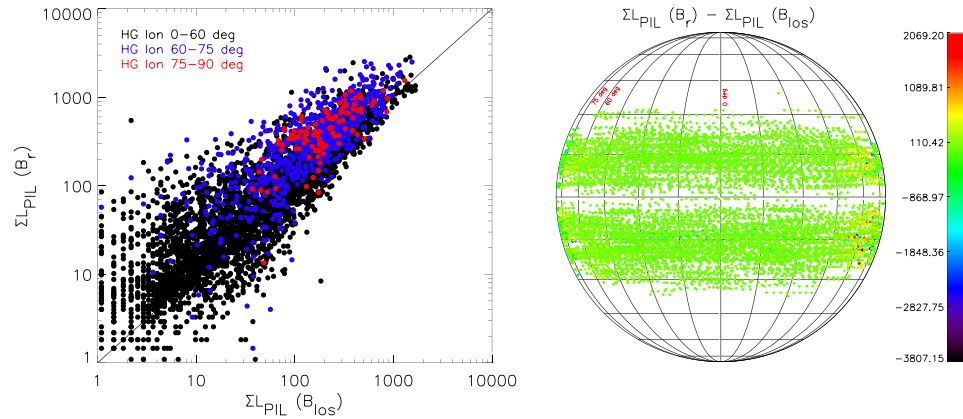
- Alpha



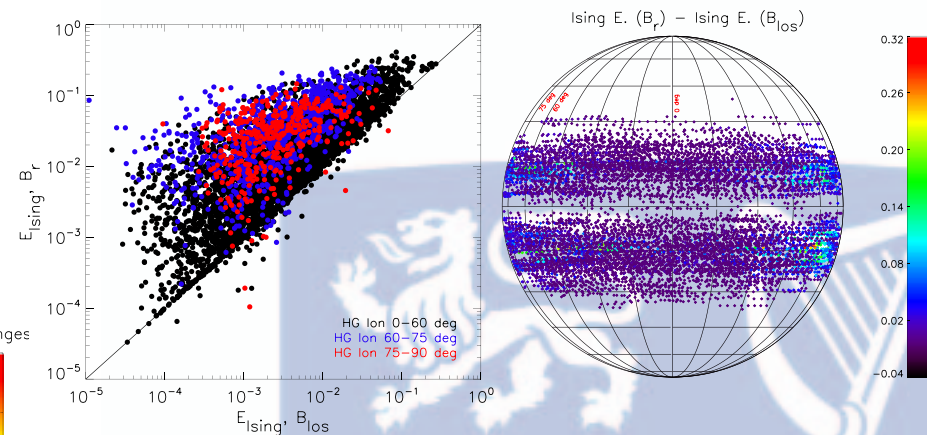


# Preliminary results

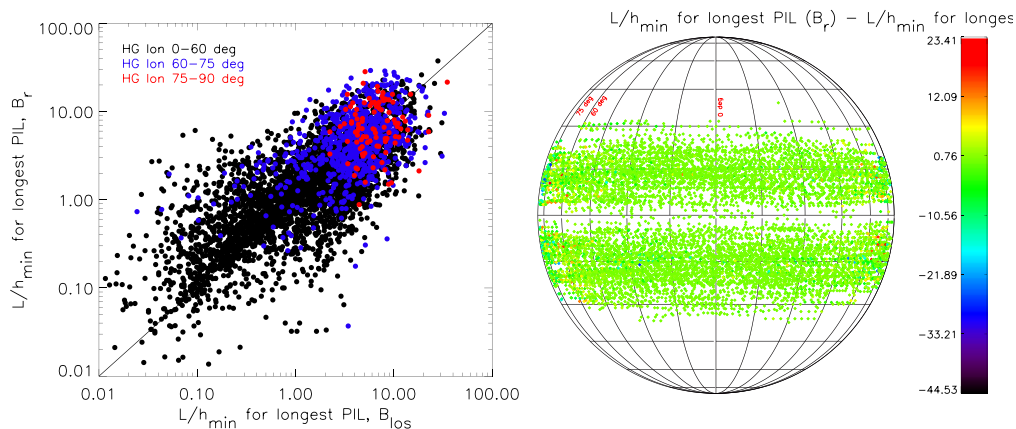
- Total length of MPIL



- Ising Energy



- Decay Index





# Summary

- FLARECAST is half way through and expecting to start producing forecasts by early 2017.
  - About 70% of PE codes have been developed and tested. Processing of the SHARP DB will start soon.
  - Coronal connectivity and fractal properties seem to be varies more with the  $B_z$  choice. MPIL-related properties are less sensitive.
  - Four out six properties do not show strong dependence with AR longitude.
  - Usefulness of properties will be determined by their flaring association.
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