

# ***Predicting Flares***

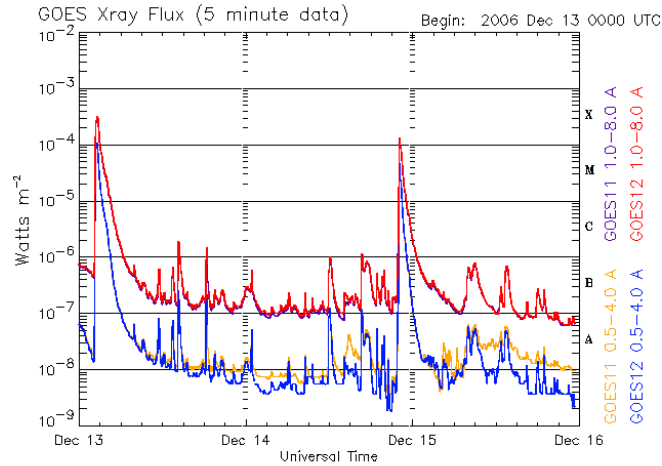
D. Shaun Bloomfield



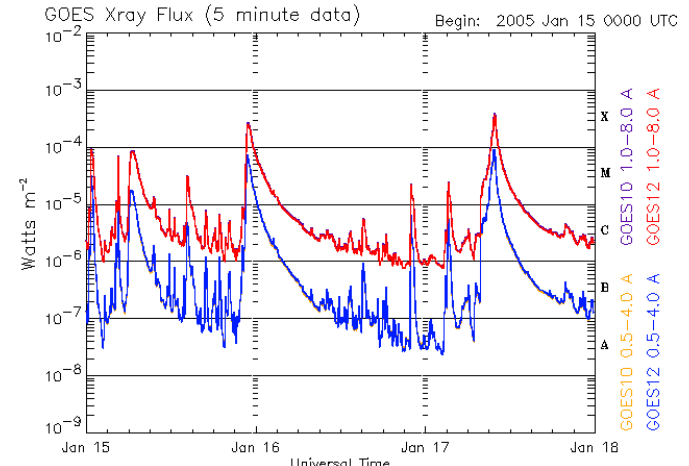
Astrophysics Research Group  
Trinity College Dublin



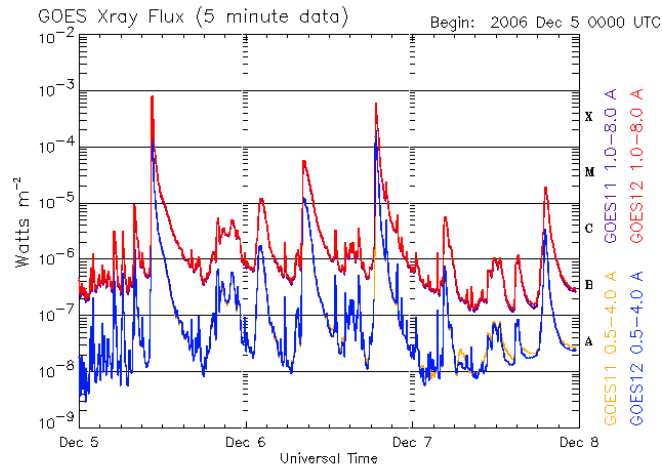
# When do large flares happen?



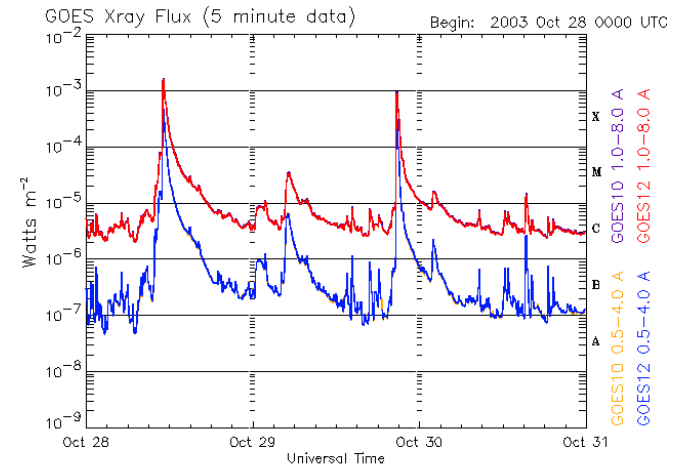
Updated 2006 Dec 15 23:31:05 UTC NOAA/SEC Boulder, CO USA



Updated 2005 Jan 17 23:56:04 UTC NOAA/SEC Boulder, CO USA



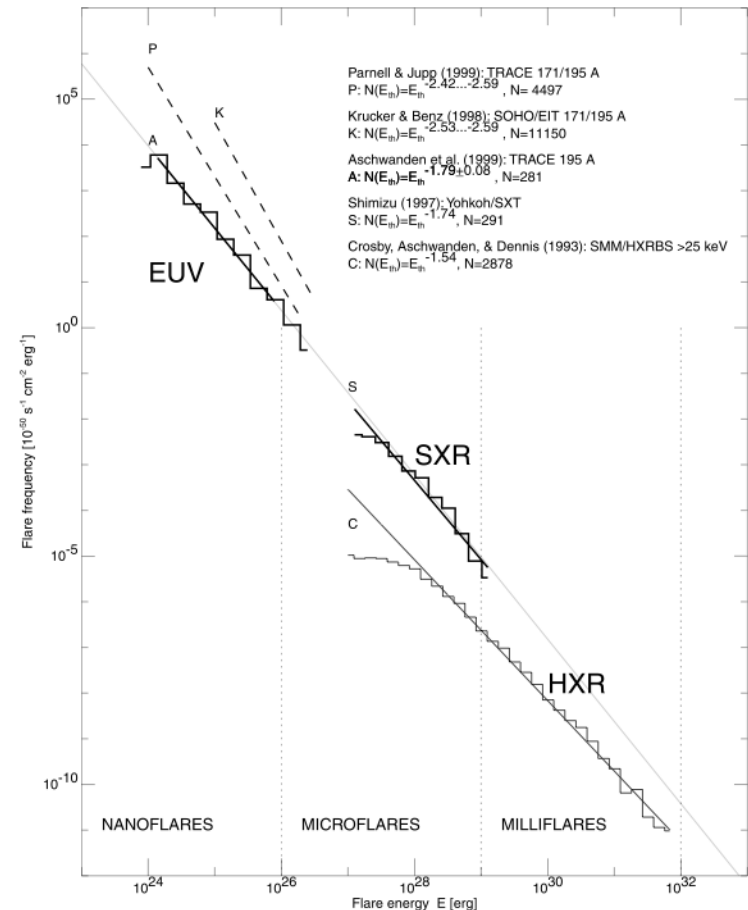
Updated 2006 Dec 7 23:36:05 UTC NOAA/SEC Boulder, CO USA



Updated 2003 Oct 30 23:56:05 UTC NOAA/SEC Boulder, CO USA

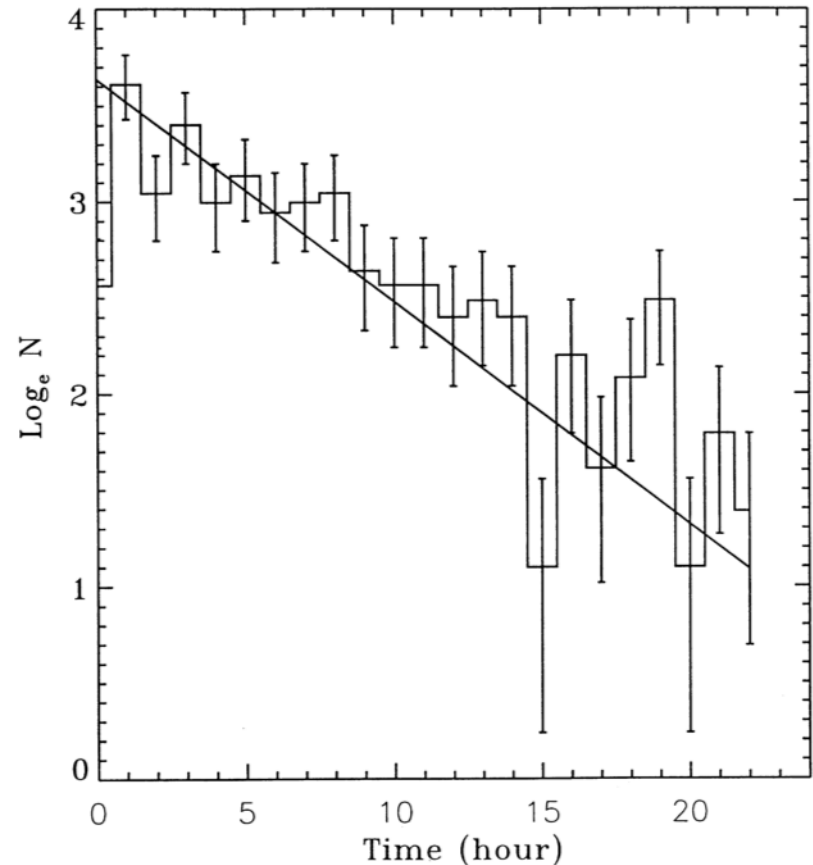
# Flare Frequencies

- Flare frequency-energy distribution power law holds over multiple decades (Aschwanden 2000)
- Can determine flare rates from numbers of events measured
- Individual active regions (ARs) have power law indices close to whole Sun value (Wheatland 2000)



# Flare Timings and Probabilities

- Flare frequency-waiting times show Poisson-like exponential distribution (Moon et al. 2001)
- Can determine probability of one or more flares above a given energy cut-off (Gallagher et al. 2002)  
$$\varepsilon = 1 - \exp(-\lambda\Delta T)$$
- Used with mean flare rates for each McIntosh class
  - no variation within class



# Bayesian Probabilities

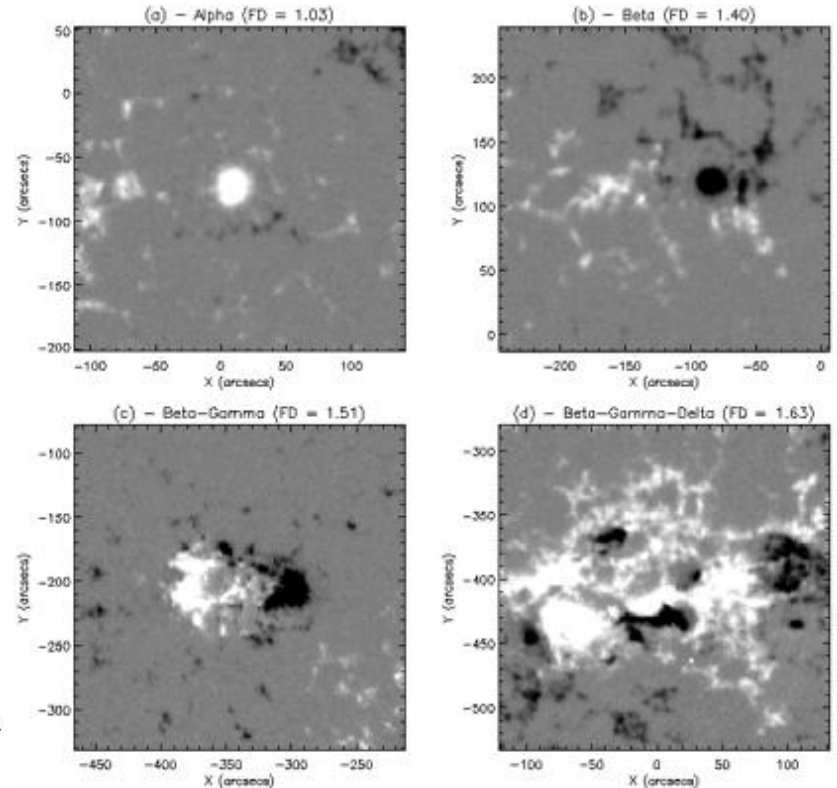
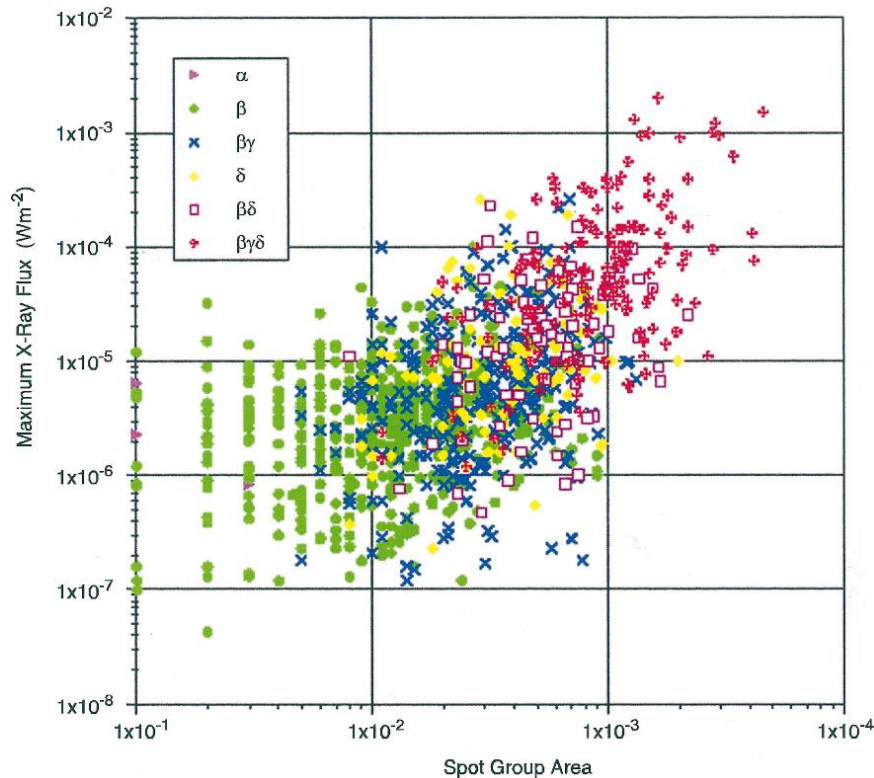
$$\text{prob}(\lambda|D, I_{\text{AR}}) = \text{prob}(D/\lambda, I_{\text{AR}}) * \text{prob}(\lambda|I_{\text{AR}}) / \text{prob}(D/I_{\text{AR}})$$

(1)                      (2)                      (3)                      (4)

- (1) – probability distribution of flare rate given flare data and AR info.
  - (2) – probability distribution of flare data given flare rate and AR info.
  - (3) – probability distribution of flare rate given AR info.**
  - (4) – probability distribution of flare data given AR info. (normalisation term)
- 
- o Can construct  $\text{prob}(D/\lambda, I_{\text{AR}})$  by combining the phenomenological eqns. (Wheatland 2004)
  - o Can convert probability distribution of flare rates (1) into the probability distribution of flare probabilities from the previous relation for Poisson-based flare probabilities

$$\lambda = \ln(1 - \varepsilon) / \Delta T$$

# Conditions for Flaring



- Peak flare magnitude vs peak spot area (Sammis et al. 2000)
  - Big, bad, and ugly?

# *Data for Analysis*

- GOES X-ray flare event listings
  - flare times, flare magnitudes, associated AR
- Solar EUV images
  - flare locations and AR association (backward extension of Sam Freeland's *SoHO*/EIT flare location archive beyond 2002)
  - From mid-2009, *PROBA2*/SWAP 171Å images at nominal 1-min cadence
- NOAA SWPC AR summaries
  - number of spots, total spot area, longitudinal extent, location, McIntosh and Mt Wilson magnetic classifications
- *SoHO*/MDI AR magnetograms
  - peak and average  $|B|$ , length and curvature of neutral line, peak and average  $dB/dl$  along neutral line, fractal dimension

# Final Data Product

- Automated code updating with additional X-ray events and AR evolution
- AR-specific flare probabilities hosted on *www.SolarMonitor.org*
  - Comparison with NOAA SWPC and Poisson-based predictions

www.SolarMonitor.org

←20081031 ←Week ←Rotation 20081101 Rotation⇒ Week⇒ 20081102→

NOAA Regions 11007

MDI Mag 20081101 19:00 MDI Cort 20081101 17:36 GHV Hα 20081101 12:40

EIT 171A 20081101 00:58 EIT 195A 20081101 05:46 XRT 20081031 17:57

Home Forecast Search News

GOES X-rays Protons Electrons

SOHO Movies

SEC Events

SSW Events

MM MotD

Summary: Activity Level -- VERY LOW -- no flares in past two days

www.SolarMonitor.org

←20081103 ←Week ←Rotation 20081104 Rotation⇒ Week⇒ 20081105→

NOAA Regions 11007

Welcome to the Flare Prediction System. This page gives the active regions on the Sun today together with each regions probability for producing C-, M-, or X-class events. The flare probabilities were calculated using NOAA Space Environment Center data from nearly eight years of data starting November 1988 and ending June 1996. The percentage probabilities are based on the number of flares produced by regions classified using the McIntosh classification scheme (McIntosh, P., 1990, *Solar Physics*, **125**, 251) during cycle 22. For example, between November 1988 and June 1996 there were 302 regions classified Eai. As this class produced 62 M-class events, the mean M-class flare rate is  $\sim 62/302$  or  $\sim 0.21$  flares per day. Assuming the number of flares per unit time is governed by Poisson statistics, we can estimate a flaring probability for the following 24-hours using  $P(\text{one or more flares}) = 1 - \exp(-\text{mean})$ , i.e.,  $P = 1 - \exp(-0.21) \sim 0.19$ , or 19% for an Eai class region to produce one or more M-class flares in the next 24-hours. See Wheatland, M. S., 2001, *Solar Physics*, **203**, 87 and Moon *et al.*, 2001, *Journal of Geophysical Research-Space Physics*, **106(A12)** 29951 for further details.

Click [here](#) for a description of the various active region classifications from the Royal Observatory of Belgium.

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Region Flare Probabilities (%)				
Number	McIntosh	C-class	M-class	X-class
	Dso	20(25)	4(1)	0(1)