Solar Cycle Variations of the Distribution of Photospheric Magnetic Flux Features Using SDO/HMI

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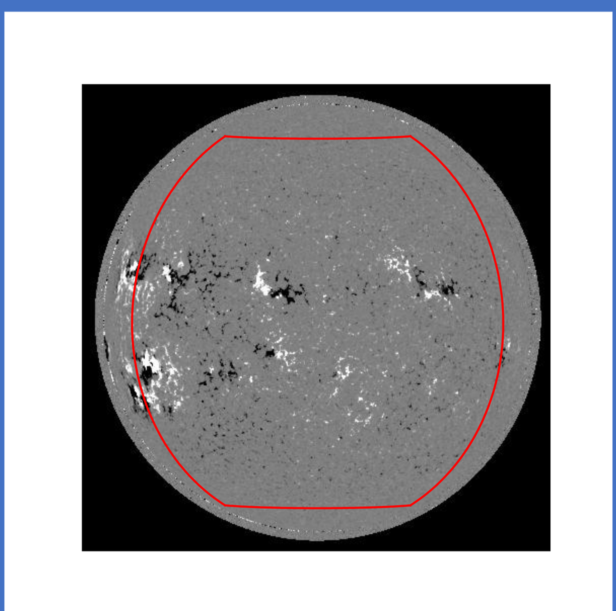
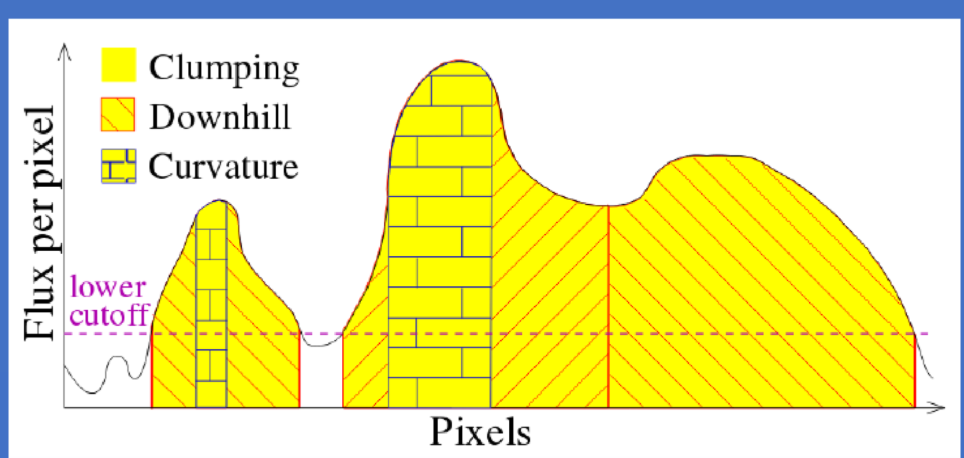
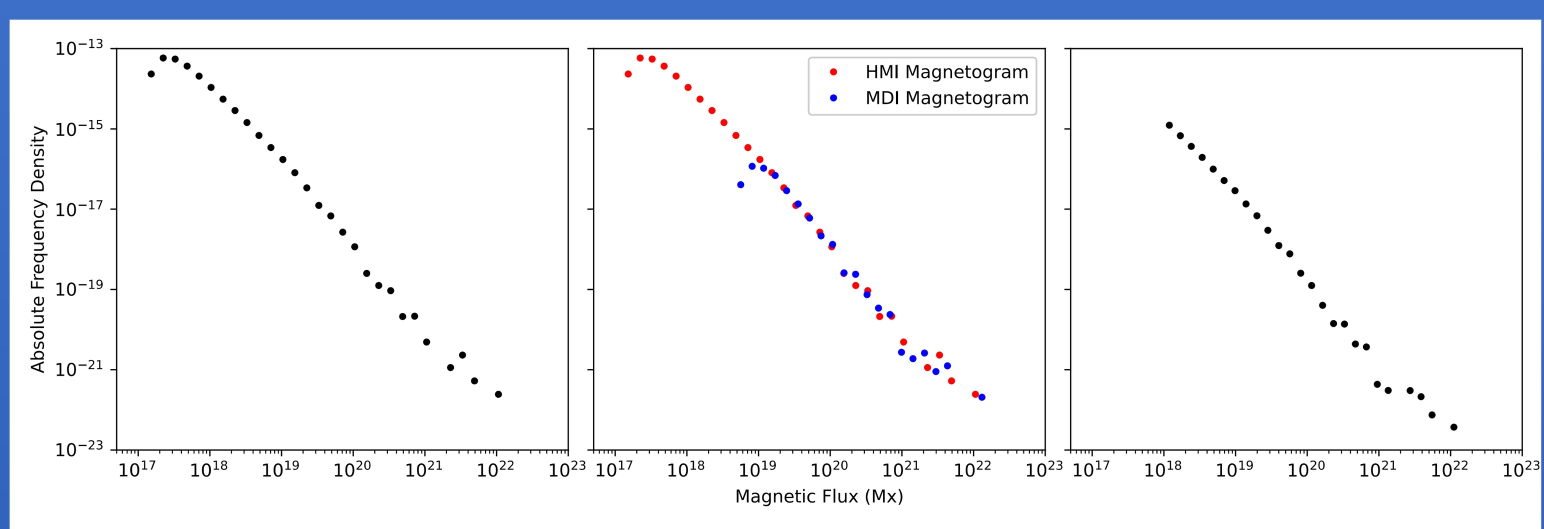
Data



- SDO/HMI line-of-sight magnetograms over full solar cycle
- 1 May 2010 to 16 March 2021; 1st and 16th of each month
- Magnetic flux feature detection: "Clumping" algorithm (e.g. Parnell et al., 2009)



- Generate histograms of magnetic flux features for each magnetogram
- Omit data < 10^{18} Mx due to instrumental resolution effects



Analysis

We have tested fits for nine different probability density functions (PDFs):

(a) Single Power Law: $f(x;\alpha) = \frac{\alpha-1}{x_0}\left(\frac{x}{x_0}\right)^{\alpha}$

(b) Exponential: $f(x;\lambda) = \lambda e^{-\lambda(x-x_0)}$

(c) Lognormal: $f(x;\mu,\sigma) = \frac{1}{x\sigma\sqrt{2\pi}} exp\left(-\frac{(\ln x-\mu)^2}{2\sigma^2}\right)$

(d) Weibull: $f(x;k,\lambda) = \frac{k}{\lambda}\left(\frac{x-x_0}{\lambda}\right)^{k-1} exp\left(-\left[\frac{x-x_0}{\lambda}\right]^k\right)$

(e) Truncated Weibull: $f(x;k,\lambda) = \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} exp\left(\left[\frac{x_0}{\lambda}\right]^k - \left[\frac{x}{\lambda}\right]^k\right)$

(f) Double Power Law (DPL): $f(x;\alpha,\beta,x_c) =$

$$\frac{(\alpha+1)(\beta+1)}{x_c\left[\beta-\alpha-(\beta+1)\left(\frac{x_0}{x_c}\right)^{\alpha+1}\right]}\begin{cases}\left(\frac{x}{x_c}\right)^{\alpha} & x \le x_c\\ \left(\frac{x}{x_c}\right)^{\beta} & x > x_c\end{cases}$$

(g) Smooth Double Power Law (DPL): $f(x;\alpha,\beta,x_c,\sigma) = \frac{\left(\frac{x}{x_c}\right)^{\alpha}\left[1+\left(\frac{x}{x_c}\right)^{\sigma}\right]^{\frac{\beta-\alpha}{\sigma}}}{\int_{x_0}^{\infty}\left(\frac{x}{x_c}\right)^{\alpha}\left[1+\left(\frac{x}{x_c}\right)^{\sigma}\right]^{\frac{\beta-\alpha}{\sigma}}dx}$

(h) Weibull-Lognormal:

$$f(x;k,\lambda,\mu,\sigma,w) = w\frac{k}{\lambda}\left(\frac{x-x_0}{\lambda}\right)^{k-1} exp\left(-\left[\frac{x-x_0}{\lambda}\right]^k\right) + (1-w)\frac{1}{x\sigma\sqrt{2\pi}} exp\left(-\frac{(\ln x-\mu)^2}{2\sigma^2}\right)$$

(i) Truncated Weibull-Lognormal:

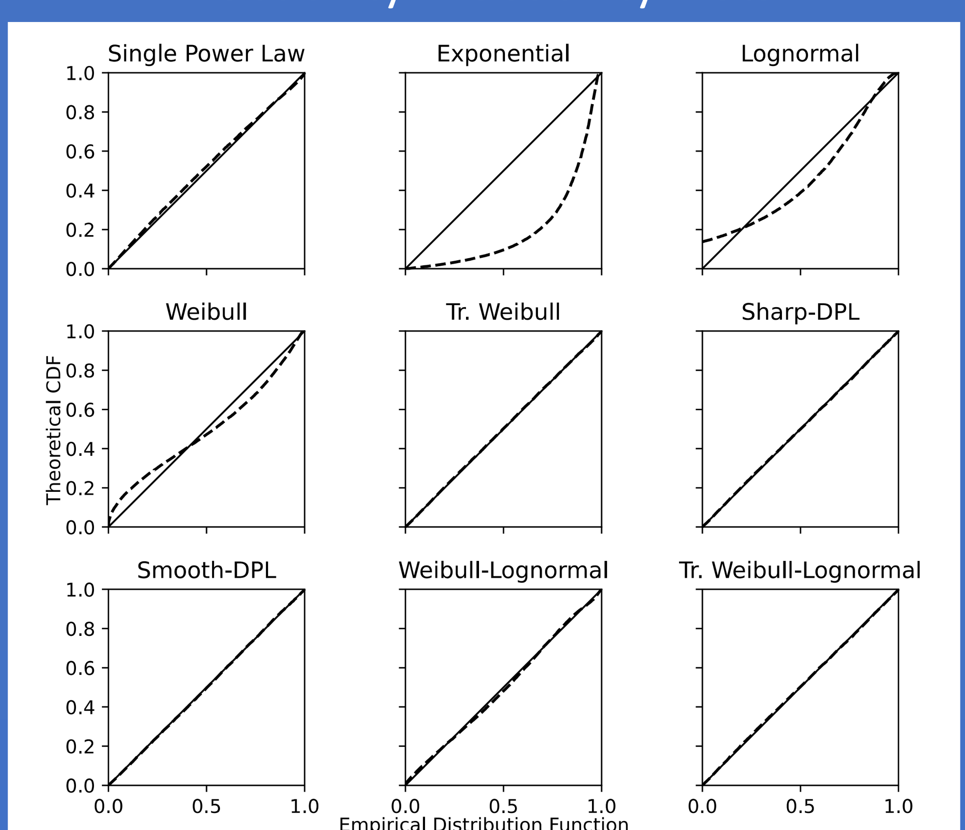
$$f(x;k,\lambda,\mu,\sigma,w) = w\frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} exp\left(\left[\frac{x_0}{\lambda}\right]^k - \left[\frac{x}{\lambda}\right]^k\right) + (1-w)\frac{1}{x\sigma\sqrt{2\pi}} exp\left(-\frac{(\ln x-\mu)^2}{2\sigma^2}\right)$$

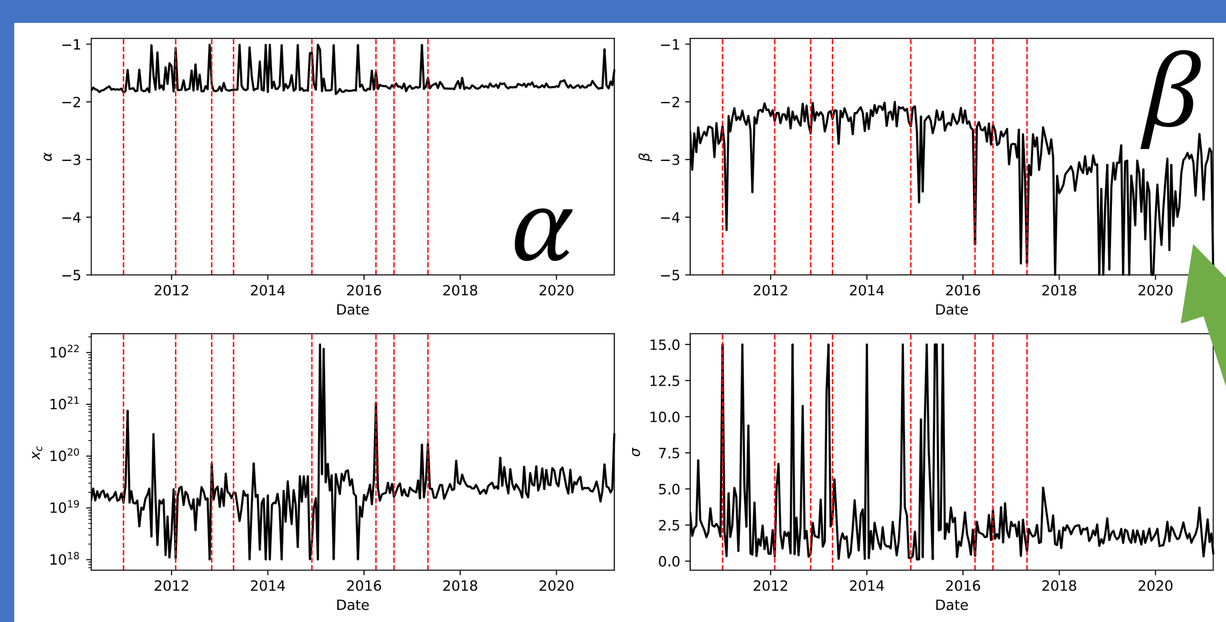
Used before: (a) and (b) (Parnell et al., 2009) ; (a) – (d) (Muñoz-Jamarillo et al., 2015)

Parameter values determined using maximum likelihood estimates

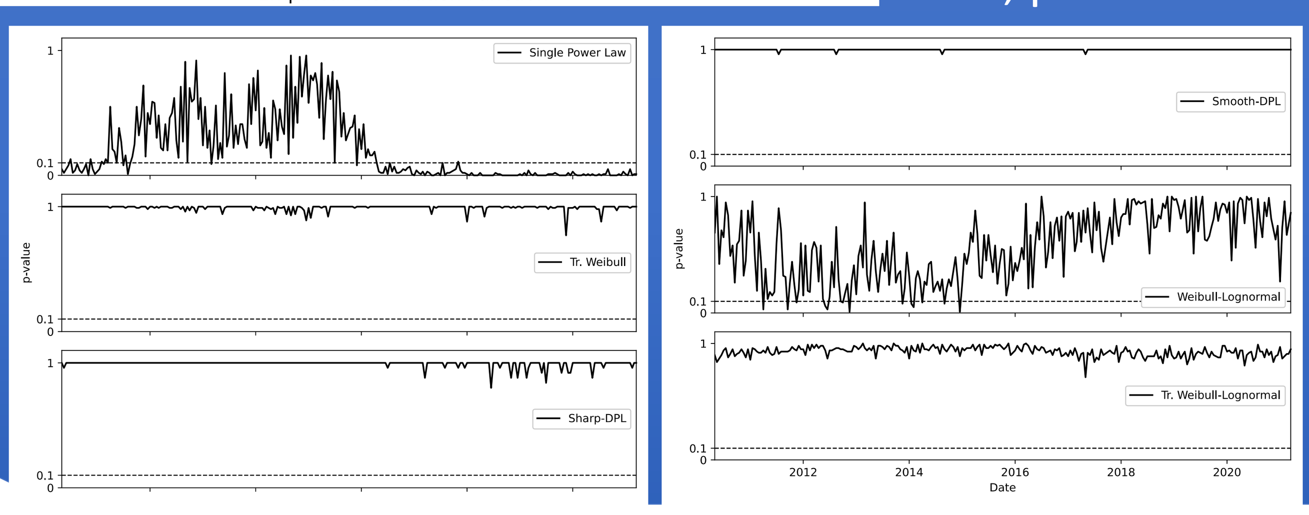
Results

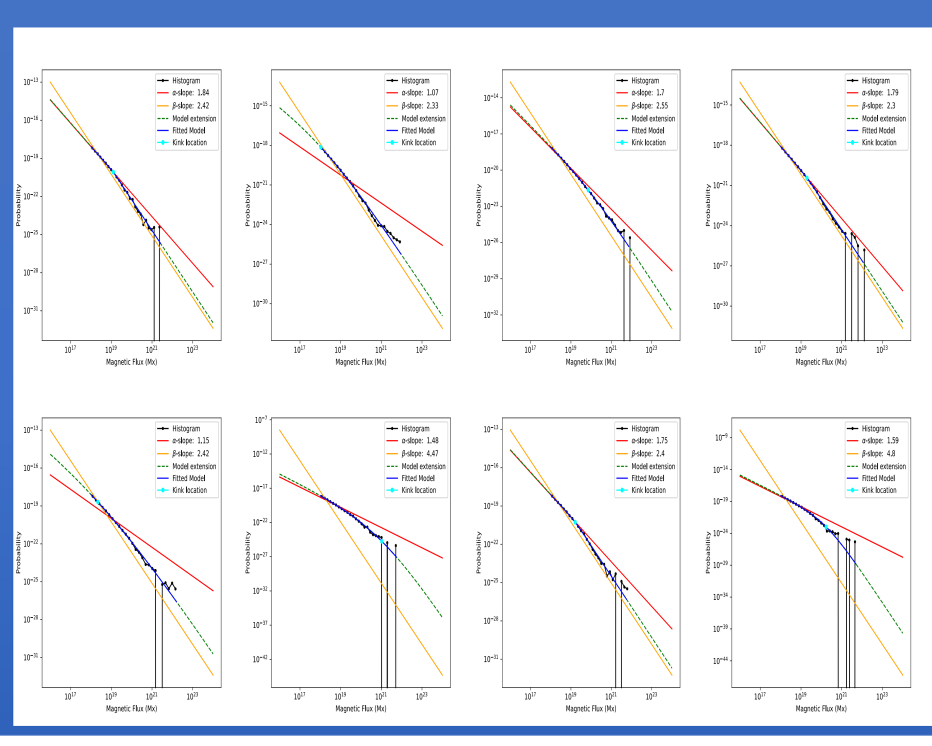
Probability-Probability Plots





Kolmogorov-Smirnov Test; p values





- Using various statistical methods: Smooth DPL (g) seems to perform best over the full cycle
- Small flux features (α) - little variation (on average) over solar cycle
- Larger flux features (β) – noticeable differences over cycle

References
Muñoz-Jaramillo, A. et al., ApJ 800, 48 (2015)
Parnell, C.E., et al., ApJ 698, 75 (2009)

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