Scaling Parameters of Active Regions for HMI pipeline

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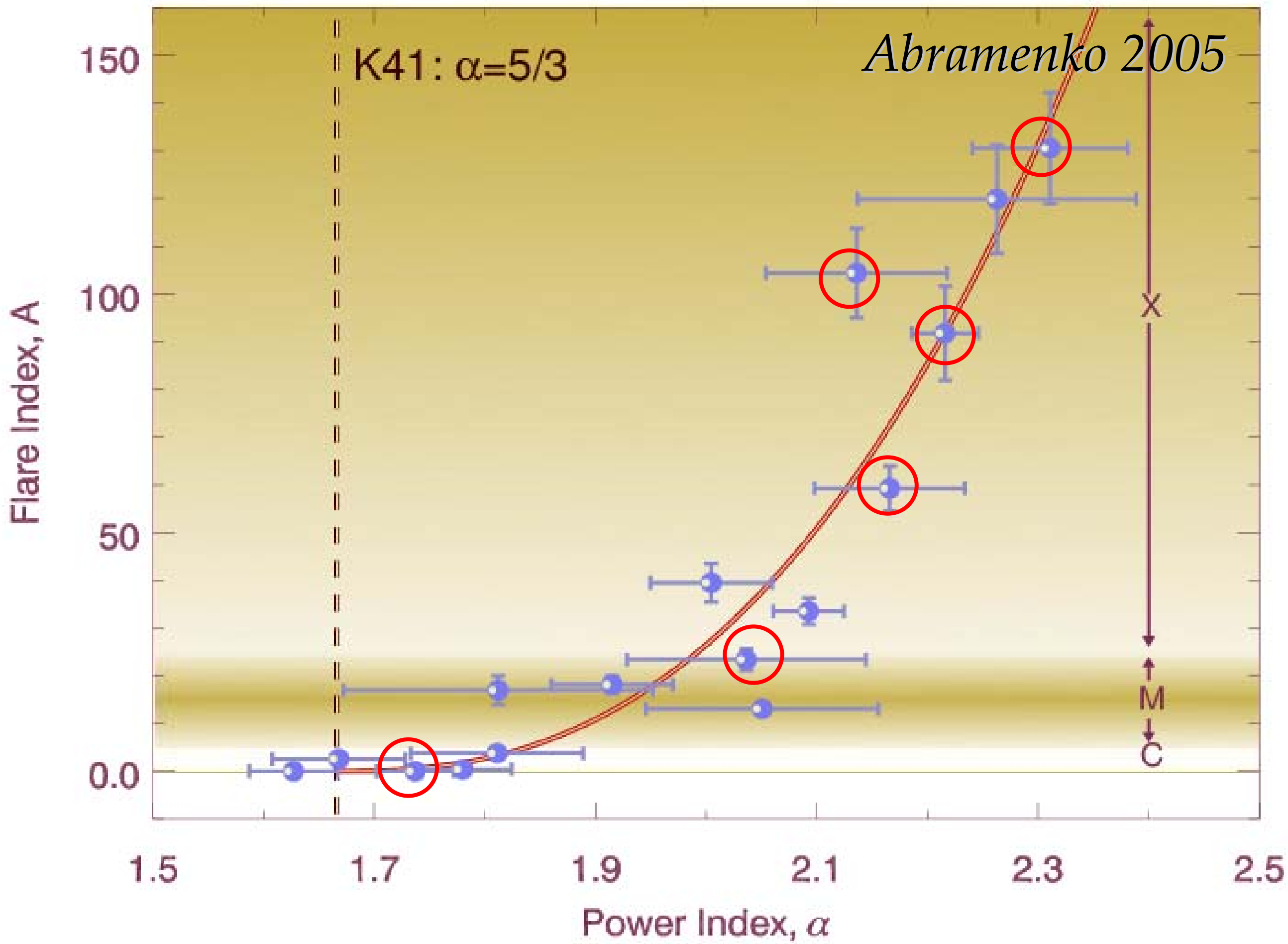
Flare Index vs Power Index

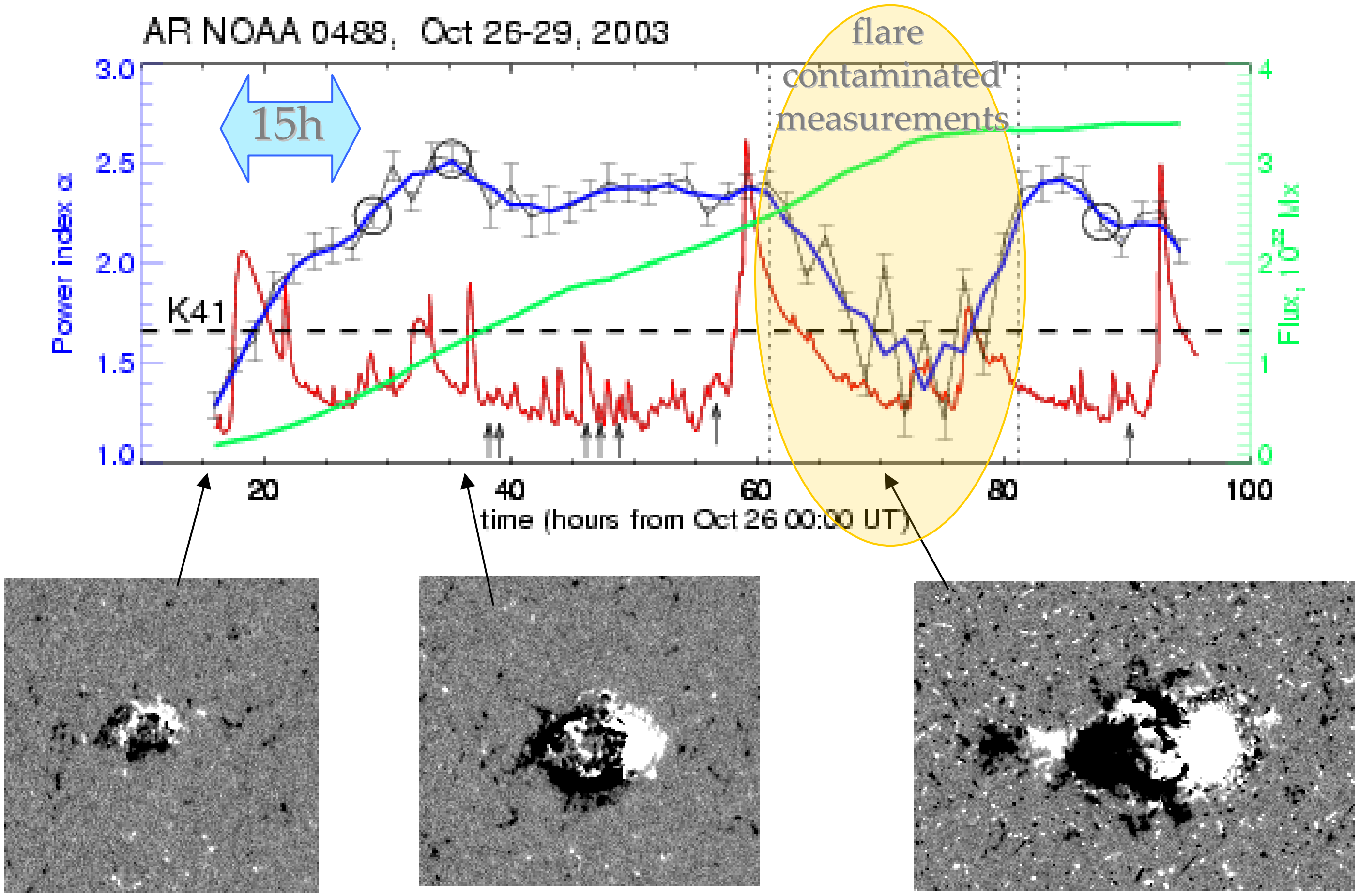


Circled points represent power indexes determined for emerging active regions

Flaring activity of an AR appears to be related to the power index, i.e. to an easily calculated parameter that seems to adequately describe the complexity of the magnetic configuration

Even at the early stage of emergence an active region magnetic field exhibits well defined characteristics inherent to those magnetic configurations prone to strong flaring

Emerging Active Region 0488



The power index peaked by the end of the first day of AR’s life, while the magnetic flux has saturated by the end of the 3rd day

Soft X-ray Flare Index

Antalova 1996 | Pevtsov 2004 *private communication*

Landi et al. 1998 | Longcope 2005 *private communication*

$$A = (100S^{(X)} + 10S^{(M)} + 1.0S^{(C)} + 0.1S^{(B)})/\tau,$$

where $S^{(j)} = \sum_{i=1}^{N_j} I_i^{(j)}$ is the sum of GOES peak intensities of a certain class, $N_j = N_X, N_M, N_C, N_B$ are the numbers of flares of X, M, C, B classes that occurred in a given active region during the time interval τ.

τ is the across-the-disk passage time (measured in days).

For example, during $\tau \approx 13$ days an active region launched flares:

X5.2 , M1.2 , C6.0

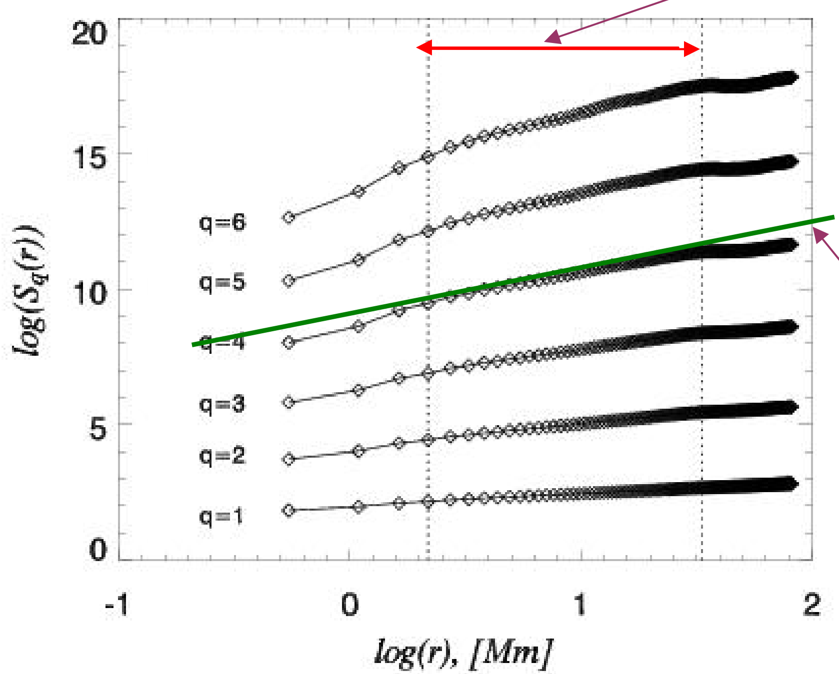
A=(520 + 12 + 6.0) / 13 = 41.4 (in units 10^{-6} W m^{-2})

Structure functions and multifractality

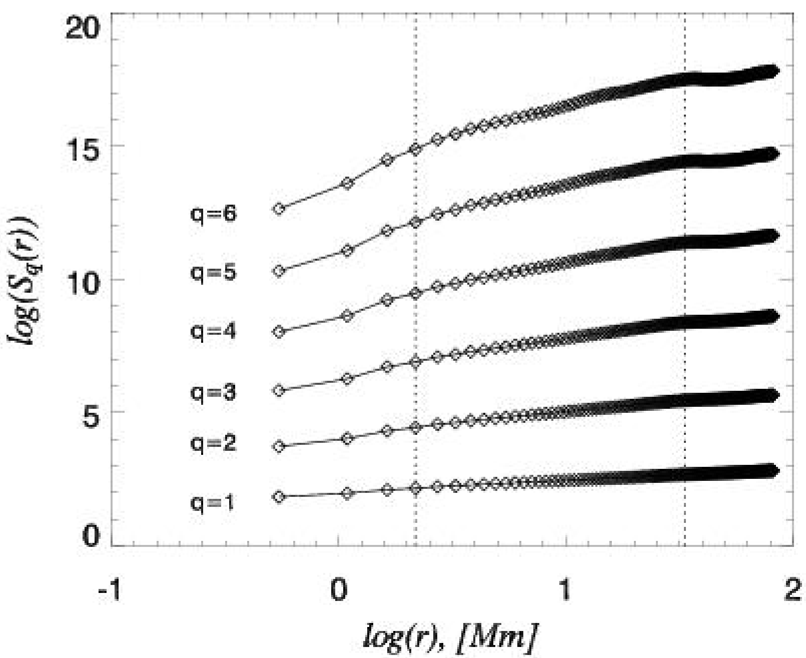
Abramenko, Yurchyshyn, Wang H., Spirock, Goode 2003, ApJ 597

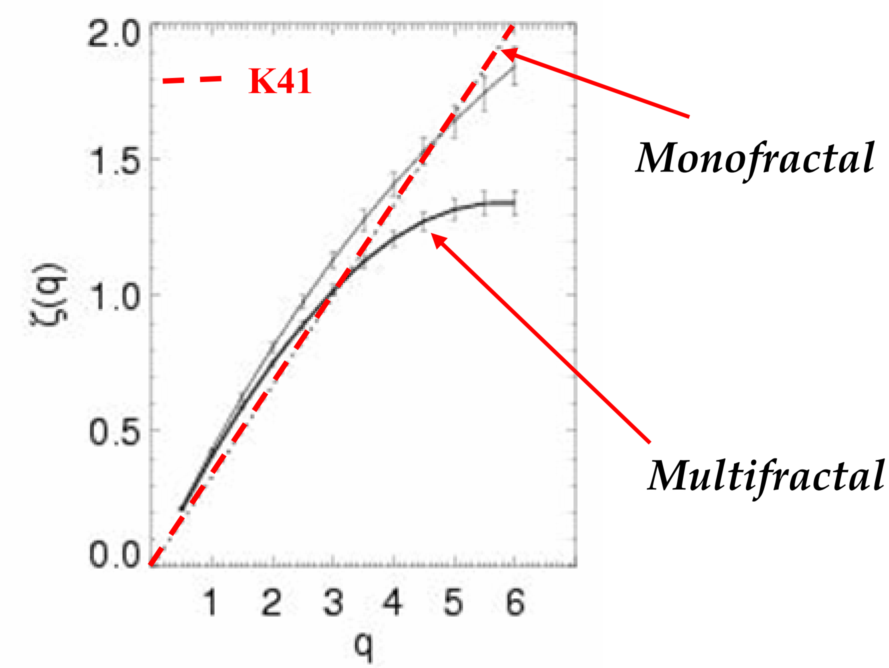
$$S_q(r) = \langle |B_z(\mathbf{x}+\mathbf{r}) - B_z(\mathbf{x})|^q \rangle \sim (r)^{\zeta(q)}.$$

Here, q is the order of a statistical moment, r is a separation vector, x is a current point on a magnetogram. <…> denotes the averaging over a magnetogram. ζ(q) is a slope within the inertial range of scales.



For example, the slope of log(S (r)) in the inertial range is ξ(4)





$$h(q) = d\zeta(q)/dq$$

When $\zeta(q)$ is concave, its derivative $h(q)$ is not a constant.

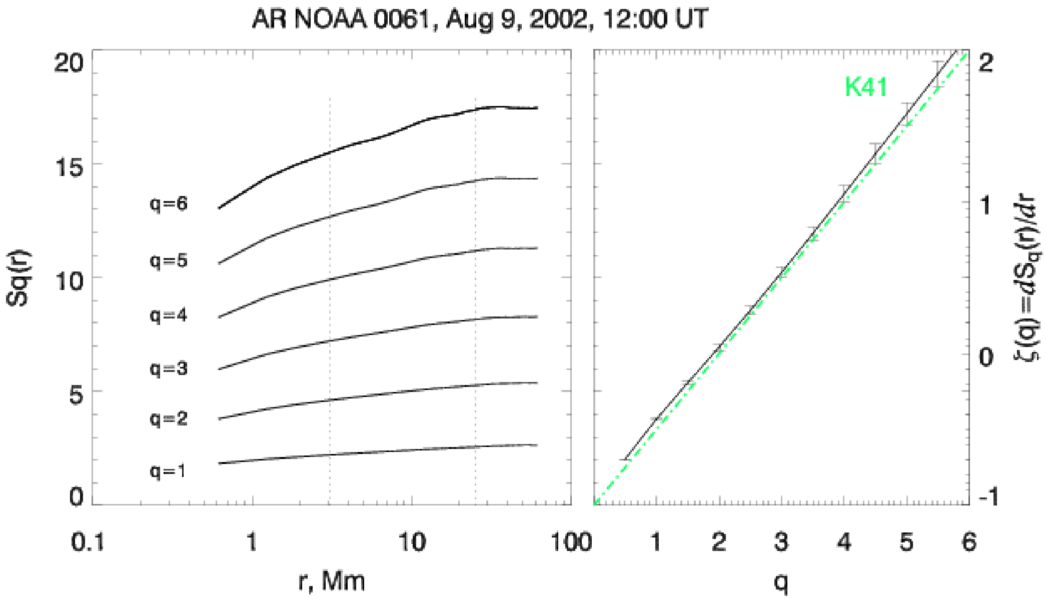
For each *h*, there is a fractal subset with an *h*-dependent dimension:

$$h \Rightarrow D(h)$$

$\zeta(q)$ is concave ⟹ Multifractal , highly intermittent structure

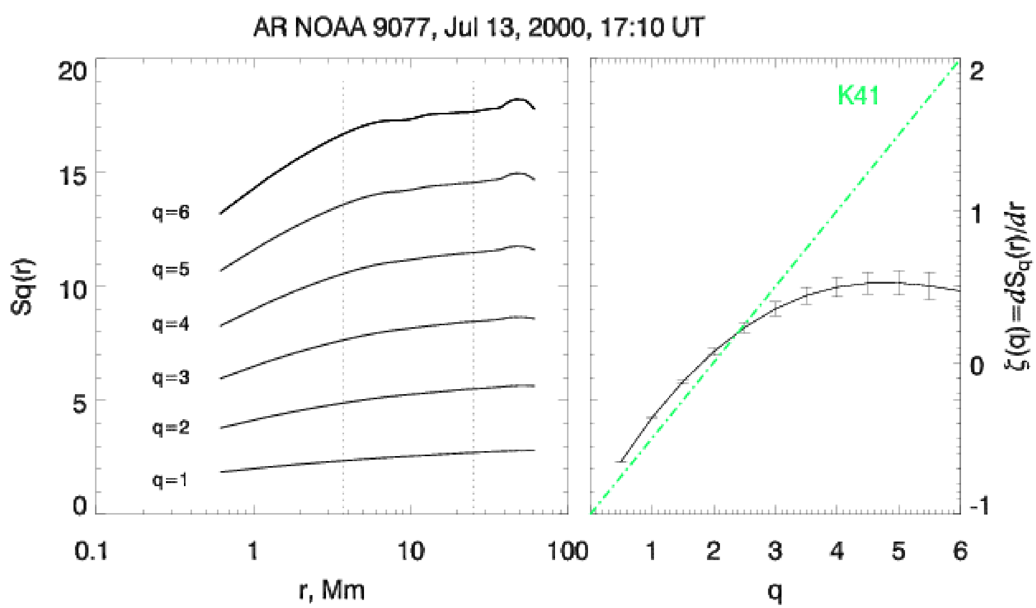
Structure functions

Flare-quiet active region



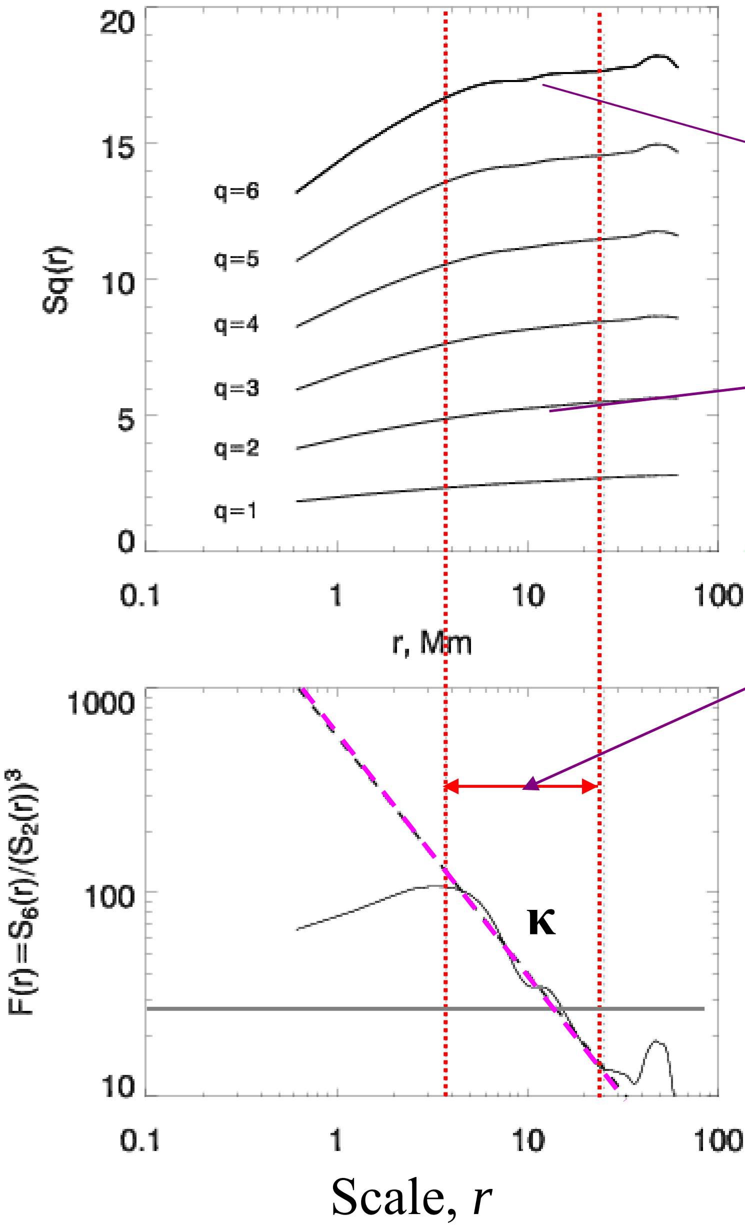
Mono-Fractal

Flaring active region



Multi-Fractal

Flatness function as an indicator of intermittency



$$F(r) = S_6(r) / (S_2(r))^3$$

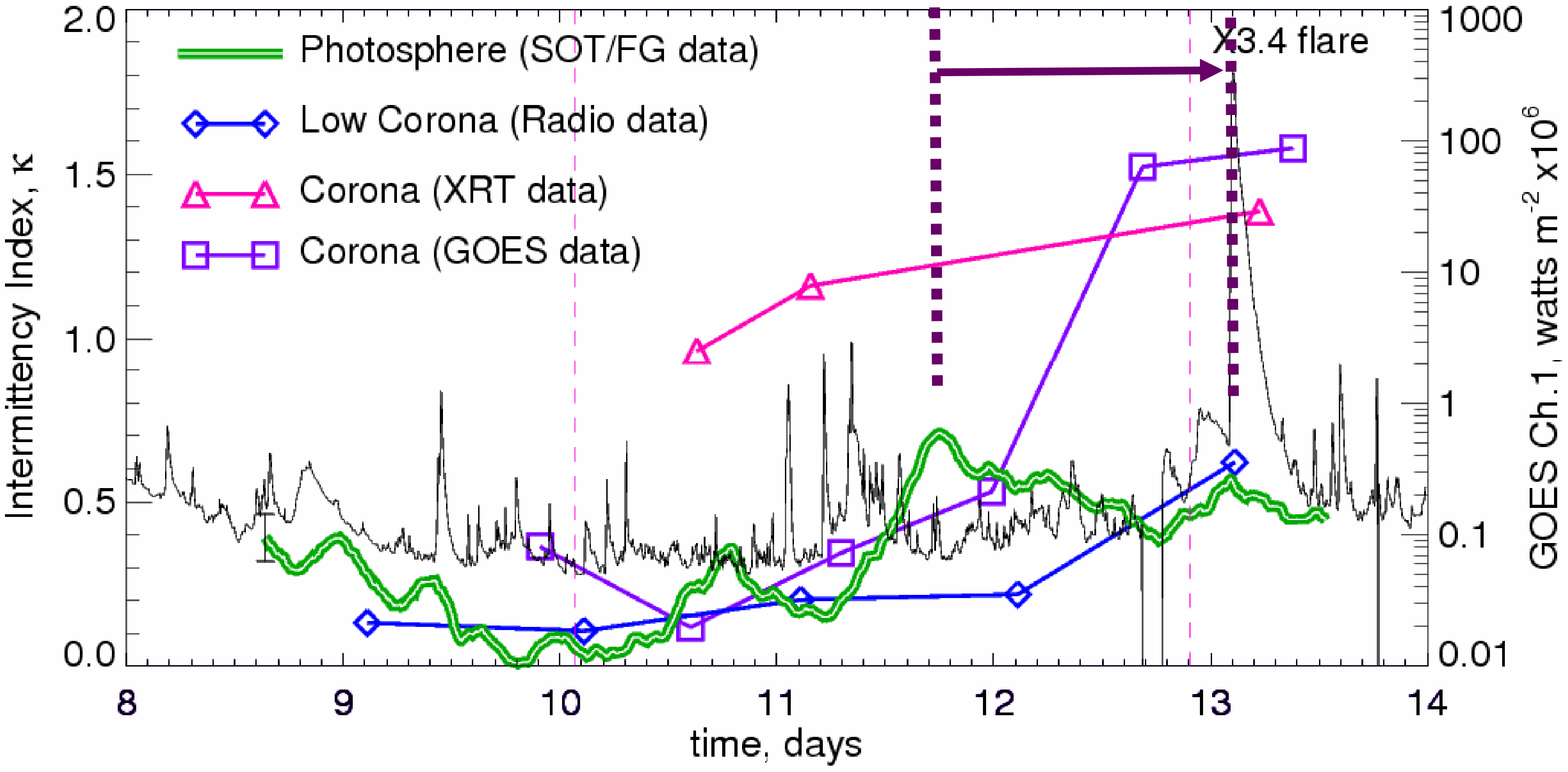
Inertial range

Fatness *F(r)* is a constant for a Gaussian variable and grows as a power law when scale *r* vanishes for an intermittent variable:

$$F(r) \sim r^{-\kappa}$$

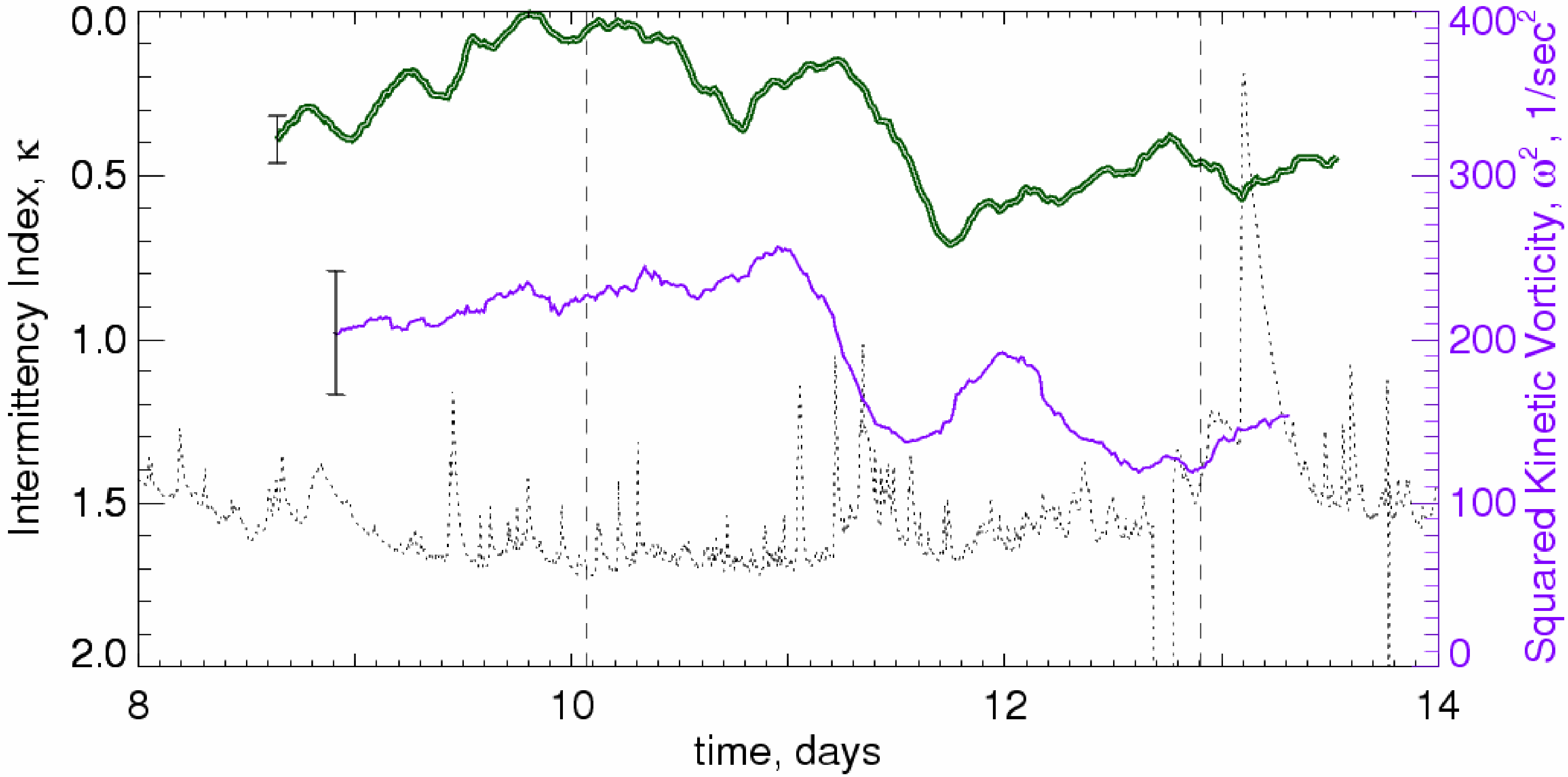
The intermittency index κ

NOAA 10930: intermittency in the photosphere and corona



Photospheric kinetic vorticity

$$\omega(\mathbf{r}) = \mathbf{lim}_{\mathbf{s}\to 0}\frac{\mathbf{1}}{\mathbf{s}}\int_{\mathbf{L}} \mathbf{v}_{\perp}(\mathbf{r})\mathbf{dl},$$



Photospheric kinetic vorticity