Reconstruction of intermittent SOL data time series by deconvolution

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Motivation

- Get better statistics of Scrape-off layer filaments
- Get good accuracy of scaling law relationships between these statistics and plasma/machine- parameters.

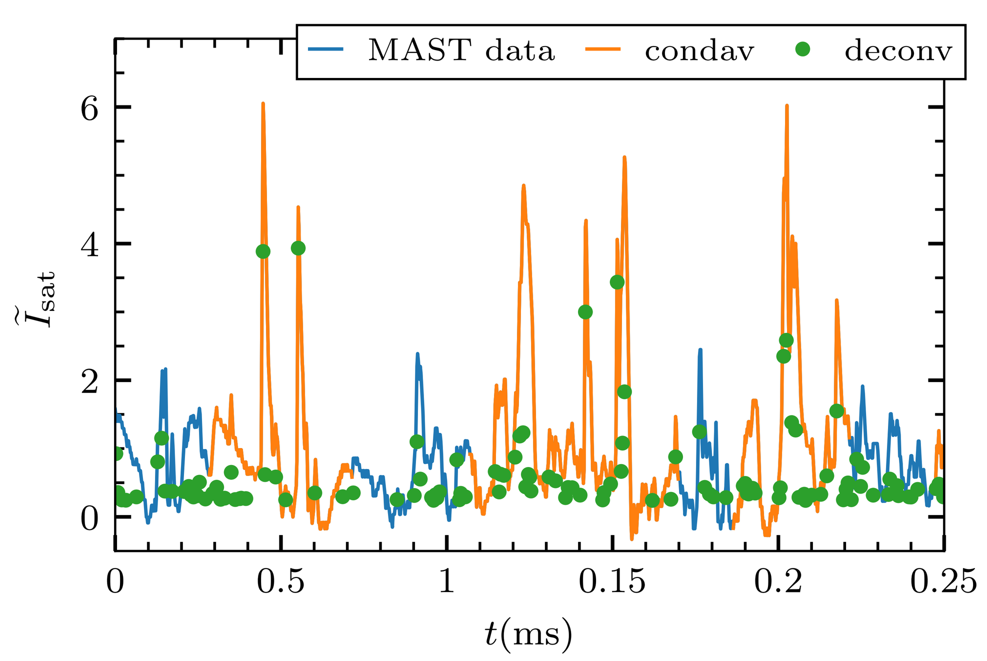

Fig. 1: An excerpt of the MAST time series (shot #21712) acquired with a reciprocating probe. This was compared to the conditionally averaged signal and estimated amplitudes from the deconvolution method.

Statistical analysis

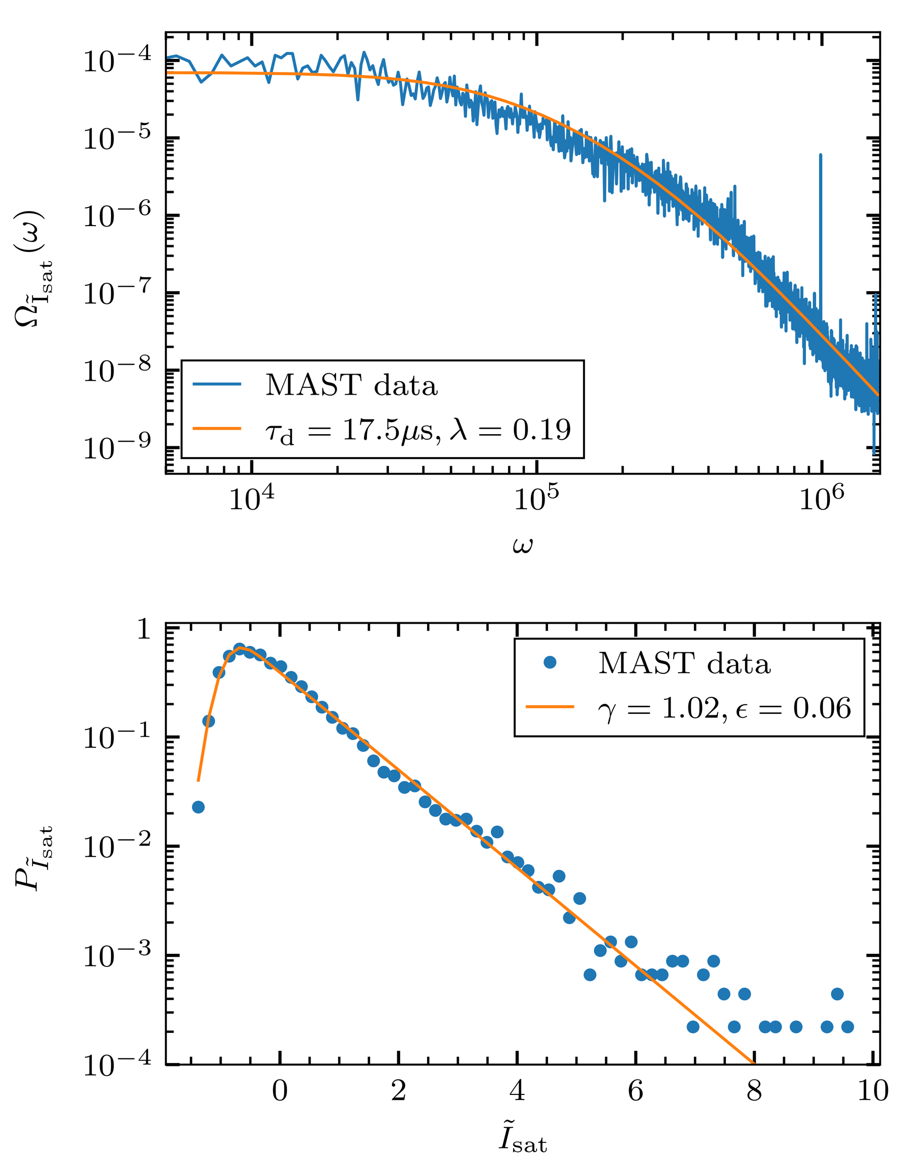

Fig. 2: The power spectral density of the ion saturation current (upper panel) with the estimated duration time and pulse asymmetry, λ. The probability distribution of the measurement data (lower panel) with estimated intermittency parameter, γ and noise to signal ratio, ϵ.

Filtered Poisson Process (FPP)

Phenomelogical model describing filaments as a superposition of uncorrelated events in,

$$\Phi_K(t) = \sum_{k=1}^{K(T)} A_k \varphi\left(\frac{t-t_k}{\tau_d}\right). \tag{1}$$

- $K(T)$ events on the interval $[0, T)$, having amplitude A_k
- Event arrival times t_k and waiting times $w_k = t_{k+1} - t_k$

Fundamental parameter is the **intermittency parameter**

$$\gamma = \frac{\tau_d}{\tau_w}, \tag{2}$$

where τ_d is a constant average duration time and τ_w is the average waiting time.

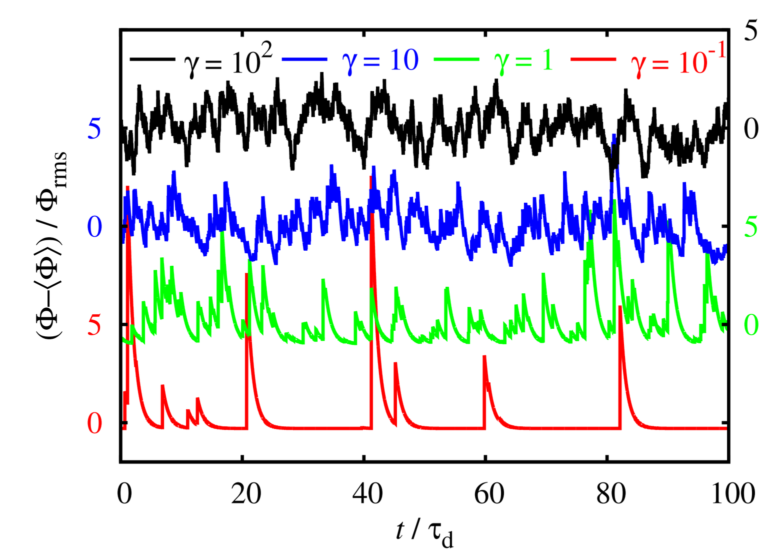

Fig. 3: Realizations of the Filtered Poisson Process (FPP) illustrating intermittency[1].

Results

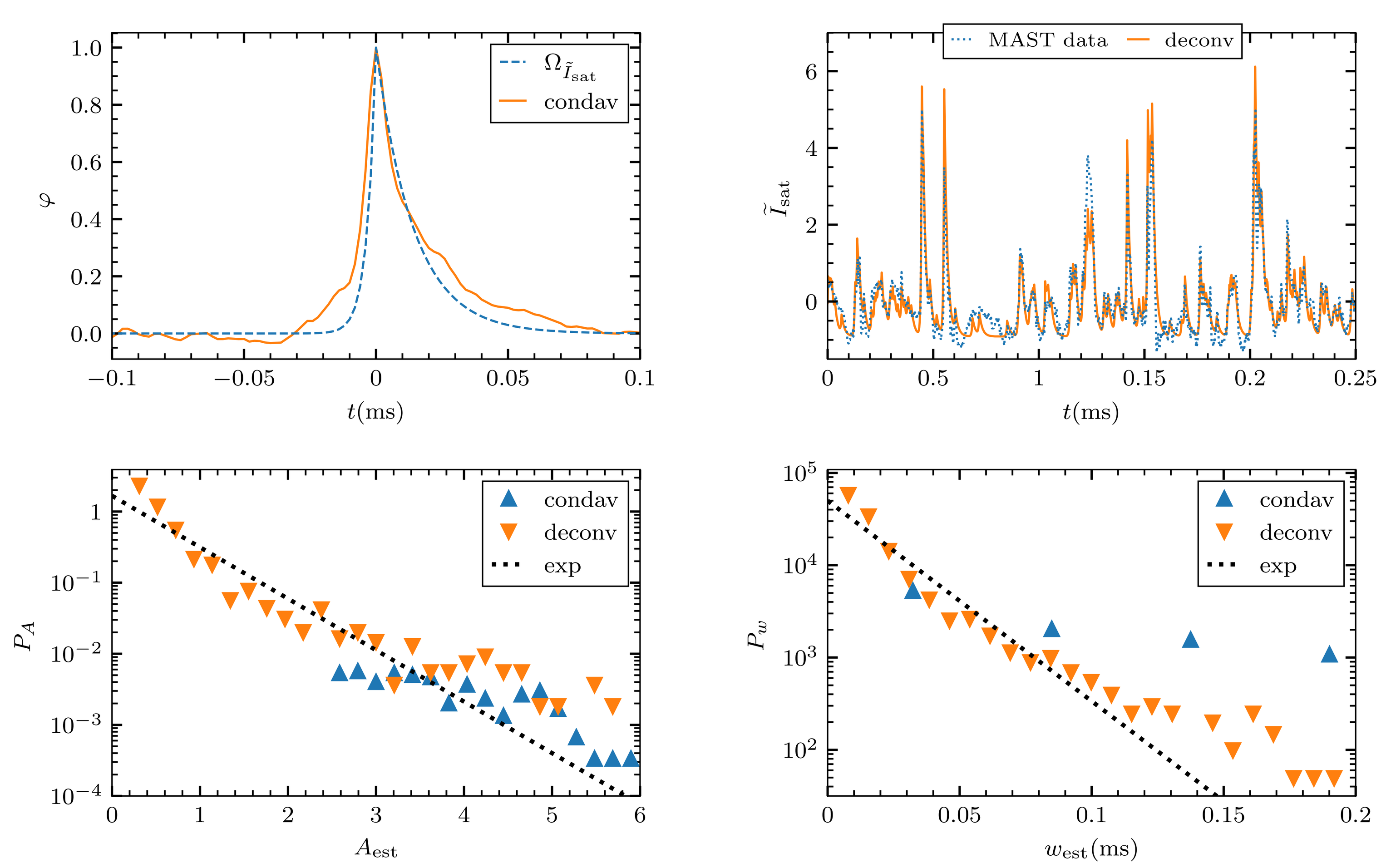

Fig. 4: Comparison of the waveforms (upper left); reconstructed time series using the estimated amplitudes from the deconvolution (upper right); comparing amplitude distributions (lower left) and the waiting time distributions (lower right) between the methods.

Richardson-Lucy Deconvolution

Rewrite FPP as a convolution in

$$\Phi_K(t) = [\varphi * f_K]\left(\frac{t}{\tau_d}\right). \tag{3}$$

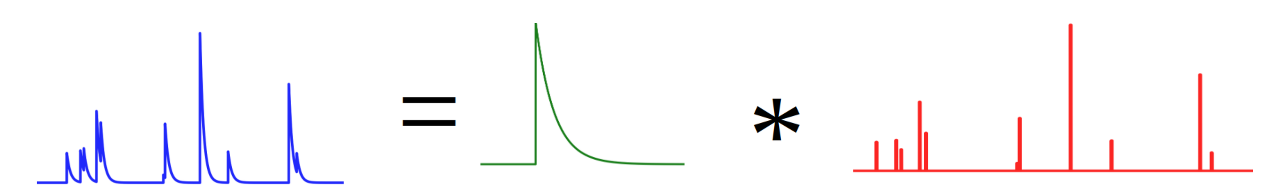

Fig. 5: We have the realization (blue) as a convolution of a pulse shape (green) and the forcing (red). The forcing consists of a delta pulse train.

The forcing, f_K describes filament amplitudes and arrival times. Iterative scheme[2,3,4] to estimate f_K,

$$f_j^{(n+1)} = f_j^{(n)} \frac{(\Phi * \widehat{\varphi})_j + b}{\left(f^{(n)} * \varphi * \widehat{\varphi}\right)_j + b} \tag{4}$$

where b is,

$$(\Phi * \widehat{\varphi})_j + b > 0 \forall j. \tag{5}$$

Conclusions

For strongly intermittent and small amount of noise

- Good agreement between FPP and measurements
- Good reconstruction of the time series
- More amplitudes and arrival times recovered compared to conditional averaging

Acknowledgements

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