Intermittency in solar flare hard X-ray light curves

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Abstract

Introduced in studies of fluid turbulence, Local Intermittency Measure (LIM) is a quantity constructed from wavelet amplitudes which characterises intermittency in time series. We show how measurements of LIM might e.g. distinguish between avalanche and cascade behaviour in flare development. We apply LIM analysis to BATSE hard X-ray measurements from several flares, all of which display episodes of intermittency across a range of scales. Neither avalanche nor cascade pictures capture the totality of events within a single flare.

Solar Flares: avalanche or cascade?

Neither avalanche nor cascade pictures capture the totality of events within a single flare. From several flares, all of which display episodes of intermittency across a range of scales.

Example: BATSE flare 174 (09/05/91)

Example: BATSE flare 1296 (“Masuda flare”)

Conclusions: future work

- LIM analysis of hard X-ray time profiles can probe the sequence of cause and effect in flares, and in particular the processes that produce rapid fluctuations/small scales
- Small scales appear in ways resembling both avalanche and cascade scenarios, sometimes at different times within the same flare
- Fermi GBM data
- Theory: relationship between HXR time profile and progress of energy release (cf. Turkmani et al., 2006); occurrence of intermittency (nonlinear feedback between particles and reconnection?)

BATSE flare 7223, 22/11/98

BATSE data

- BATSE on the Compton Gamma-Ray Observatory: 64 ms time resolved hard X-ray data in four broad energy channels:
  - Channel 1: 25 – 50 keV
  - Channel 2: 50 – 100 keV
  - Channel 3: 100 – 300 keV
  - Channel 4: > 300 keV

- * assume HXR time profile reflects development of energy release


Figure 2. X-ray light curves in Channel 1 from BATSE flare 174, 9 May 1991, 1208 UT (left) and corresponding LIM scaleogram (right).

Figure 3. X-ray light curves in Channels 1 (top) and 2 (bottom) from the Masuda flare, BATSE flare 1296, on 13 January 1992, 22:01 UT (left) and corresponding LIM scaleograms (right).

Figure 4. X-ray light curves in Channels 1 (top) and 2 (bottom) from BATSE flare 174, 9 May 1991, 1208 UT (left) and corresponding LIM scaleogram (right). “Stalactites” in the second, minor peak (~100s) resemble those in the latter. See Dinkelaker and MacKinnon (2012b).

Figure 5. X-ray light curves in Channels 1 (top) and 2 (bottom) from the Masuda flare, BATSE flare 1296, on 13 January 1992, 22:01 UT (left) and corresponding LIM scaleograms (right). “Stalagmites” in the second, minor peak (~100s) resemble those in the latter. See Dinkelaker and MacKinnon (2012b).


Figure 7. X-ray light curves in Channel 1 from BATSE flare 174, 9 May 1991, 1208 UT (left) and corresponding LIM scaleogram (right).

Figure 8. X-ray light curves in Channels 1 (top) and 2 (bottom) from the Masuda flare, BATSE flare 1296, on 13 January 1992, 22:01 UT (left) and corresponding LIM scaleograms (right). “Stalactites” in the second, minor peak (~100s) resemble those in the latter. See Dinkelaker and MacKinnon (2012b).

Figure 9. X-ray light curves in Channels 1 (top) and 2 (bottom) from BATSE flare 7223, 22 November 1998, 06:06 UT (left) and corresponding LIM scaleograms (right). “Stalagmites” in the first peak resemble avalanche behaviour, while structures in the second peak recall cascade scenarios (cf. Fig. 2). See Dinkelaker and MacKinnon (2012b).


Figure 11. X-ray light curves in Channel 1 from BATSE flare 174, 9 May 1991, 1208 UT (left) and corresponding LIM scaleogram (right).

Figure 12. X-ray light curves in Channels 1 (top) and 2 (bottom) from the Masuda flare, BATSE flare 1296, on 13 January 1992, 22:01 UT (left) and corresponding LIM scaleograms (right). “Stalactites” in the second, minor peak (~100s) resemble those in the latter. See Dinkelaker and MacKinnon (2012b).

Figure 13. X-ray light curves in Channels 1 (top) and 2 (bottom) from BATSE flare 7223, 22 November 1998, 06:06 UT (left) and corresponding LIM scaleograms (right). “Stalagmites” in the first peak resemble avalanche behaviour, while structures in the second peak recall cascade scenarios (cf. Fig. 2). See Dinkelaker and MacKinnon (2012b).


Figure 15. X-ray light curves in Channel 1 from BATSE flare 174, 9 May 1991, 1208 UT (left) and corresponding LIM scaleogram (right).

Figure 16. X-ray light curves in Channels 1 (top) and 2 (bottom) from the Masuda flare, BATSE flare 1296, on 13 January 1992, 22:01 UT (left) and corresponding LIM scaleograms (right). “Stalactites” in the second, minor peak (~100s) resemble those in the latter. See Dinkelaker and MacKinnon (2012b).

Figure 17. X-ray light curves in Channels 1 (top) and 2 (bottom) from BATSE flare 7223, 22 November 1998, 06:06 UT (left) and corresponding LIM scaleograms (right). “Stalagmites” in the first peak resemble avalanche behaviour, while structures in the second peak recall cascade scenarios (cf. Fig. 2). See Dinkelaker and MacKinnon (2012b).


Figure 19. X-ray light curves in Channel 1 from BATSE flare 174, 9 May 1991, 1208 UT (left) and corresponding LIM scaleogram (right).

Figure 20. X-ray light curves in Channels 1 (top) and 2 (bottom) from the Masuda flare, BATSE flare 1296, on 13 January 1992, 22:01 UT (left) and corresponding LIM scaleograms (right). “Stalactites” in the second, minor peak (~100s) resemble those in the latter. See Dinkelaker and MacKinnon (2012b).

Figure 21. X-ray light curves in Channels 1 (top) and 2 (bottom) from BATSE flare 7223, 22 November 1998, 06:06 UT (left) and corresponding LIM scaleograms (right). “Stalagmites” in the first peak resemble avalanche behaviour, while structures in the second peak recall cascade scenarios (cf. Fig. 2). See Dinkelaker and MacKinnon (2012b).