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Are Giant Pulses Evidence of Self-Organized Criticality?

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1. Introduction

The statistical distributions of certain giant pulse (GP) properties appear to be well described by power laws. This suggests that the emission mechanism that produces giant pulses is a scale-invariant one. In turn this may indicate that the source of the GPs is in a state of self-organized criticality (SOC). For a recent discussion of SOC see Sornette *et al.* (1995).

Prior to this conference, the only pulsars reported to exhibit GPs were the Crab pulsar, PSR B0531+21 (Lundgren et al. 1995), and the millisecond pulsar PSR B1937+21 (Cognard et al. 1996). However, at the conference it was reported that giant *micro*pulses had recently been observed from PSR J0437−4715 (Ables and McConnell, this volume). In all cases the statistical distributions of observed GP heights and/or fluxes are found to be well described by simple power laws. The arguments in this note apply to all these pulsars.

Table 1 briefly summarizes the power law functions fitted to the GP distributions of PSR B0531+21 and PSR B1937+21 (see Ables and McConnell, these proceedings, for a discussion of PSR J0437−4715). For consistency and comparison with the literature on SOC we have converted where necessary fitted probability distributions to probability *density* functions.

Table 1. Exponents of GP Probability Density Distributions

Pulsar	ν_{obs} (MHz)	$\alpha_{main\ pulse}$	$\alpha_{interpulse}$	Ref.	Note
PSR B0531+21	146	-3.5	-3.8	1	A
	812.5	-3.46 ± 0.04	-3.46 ± 0.04	2	B
	812.5	-3.3		2	C
PSR B1937+21	430	-2.8 ± 0.1	-2.8 ± 0.1	3	D

1. Argyle & Gower 1972. 2. Lundgren et al. 1995. 3. Cognard et al. 1996.

A. GP 'heights'. Exponents from line-by-eye fits.
B. GP 'flux-density' (proportional to observed flux). Fit to tail of combined histogram for main and interpulse.
C. Bimodal fit to weak and giant main pulse 'flux-density' (See B). The weak pulses are approximately fitted by a Dirac delta function; the GPs by a power law with a low flux cutoff approximately 33 times the mean weak pulse flux.
D. Single distribution for normalized main and interpulse GP 'amplitudes'.

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2. Discussion

We suggest that the mechanism generating GPs is in a self-organized critical state (SOCS). The SOCS is characterized by spatial and temporal scale invariance. For at least some systems exhibiting SOC the spatial extent of an 'avalanche' is directly proportional to the energy redistributed or released by it (We use 'avalanche' in a general sense to mean a rapid re-arrangement of some part of the system). In these cases the absence of a natural length scale in the SOCS results in a power law probability density function for the total energy redistributed or released during an avalanche. If we assume that observed GP fluxes and heights scale with the total energy released during a GP then it is possible that the mechanism generating GPs is in the SOCS.

There may be problems with this assumption. For instance, the bandwidth of the receiver may be less than that of the GPs. Furthermore, the background noise from the Crab nebula means that only those parts of a GP with the greatest flux density can be observed. Finally Lundgren *et al.* found that the duty cycle of the Crab pulsar was shorter than the duration of some GPs. This would lead to a deficit in the number of longer duration GPs observed. (This might explain the deficit of large flux GPs in the observations of Lundgren *et al.* since larger energy pulses would on average take longer in the SOC paradigm.) On the other hand the conclusions of Lundgren *et al.* are to be compared with more recent observations by Hankins *et al.* (this volume).

If the mechanism generating GPs is indeed in the SOCS, then the GP durations should be scale invariant. In other words the model predicts that the probability density function for the duration of the GPs will be a power law. Confirmation of this prediction may be complicated by at least two factors. First, the duration of a GP may exceed the widest observable pulse width due to beaming and rotation of the pulsar. Second, the width of a GP may also depend on the spatial extent of the emitting region at the time of observation and on the change in this size during observation.

In this note, a detailed GP emission mechanism is not proposed. However, turbulence in neutral non-ionized fluids is thought to exhibit spatial and temporal scale invariance. It may be that GPs are linked to turbulence in the magnetosphere.

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