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Sandpile modelling of pellet pacing in fusion plasmas

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Sandpile models have been used to provide simple phenomenological models without incorporating the detailed features of a fully featured model. The Chapman sandpile model (Chapman et al *Physical Review Letters* 86, 2814 (2001)) has been used as an analogue for the behaviour of a plasma edge, with mass loss events (MLEs) being used as analogues for (and anagrams of) ELMs. Here we modify the Chapman sandpile model to form comparisons with pellet pacing, which is used to reduce or eliminate ELMs. We use two different versions of the Chapman model, one in which the system is allowed to relax following an avalanche before further sand (dx) is added (classic model), and one in which further sand is added while an avalanche is propagating (running model). For this purpose, we modify the models in two different ways. First, we increase the amount of sand added at each time step, so that we move from the low driving model typically used in sandpile modelling to a high driving model. Second, we add 'bursts' of sand at intervals which are synchronised to MLEs in the sandpile, by way of comparison with pellet injection in a fusion plasma. We then analyse the behaviour of the sandpile in these new models, focusing on changes in the total system size, and on the maximum MLE size (by way of analogy with maximum ELM size). We observe that at low dx, potential energy (E_p) varies with dx in the running model, while E_p remains constant in the classic model. Probability distribution functions of waiting times between MLEs are identical for common values of dx/Z_c, as dx and the critical gradient, Z_c, are varied. Waiting times are observed to scale inversely with fuelling in the classic model, consistent with the observation that E_p is unchanged, such that MLEs depend on the amount of sand in the system, and not on the rate at which the sand builds up. Analysis of E_p/E_{pMax} against dx/Z_c for increasing dx shows that step changes occur, often at integer ratios. An heuristic explanation is suggested for this behaviour. At very high driving, the final state of the running model can be determined analytically given the value at cell $n = 1$. At extremely high driving, E_p increases with dx in the classic model, as the cells at the edge do not exceed the critical gradient, while those at the core do exceed the critical gradient.

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