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Bridging the gap between ab initio MHD modelling and avalanche models of solar flares

Solar flares have long puzzled physicists due to their complex and multiscale nature and significant impact on Earth. The prediction of solar flares is challenging because the underlying physical processes are not yet fully understood and cannot yet be observationally resolved. Recent advances have been made using powerful numerical tools such as magnetohydrodynamic (MHD) simulations, though these models are still too computationally prohibitive for real-time prediction. Alternatively, less computationally intensive models, such as avalanche models, have shown promise for real-time solar flare prediction by effectively reproducing solar statistics, such as the distribution of events described by power-laws. However, these cellular automata models suffer from ambiguous physical interpretations.

To bridge the gap between MHD simulations, avalanche models, and real-time forecasting, we investigate the conditions under which cutting-edge MHD simulations can replicate the power-law statistics observed in both the sun and avalanche models. We assess these conditions for simple twisted flaring loops with the PLUTO code and in realistic simulations of the turbulent chromosphere and corona with the Bifrost code. Additionally, we evaluate the validity of the assumptions inherent in avalanche models by verifying if these assumptions are coherent with energy release patterns observed in MHD simulations. Our study aims to provide a solid physical foundation for avalanche models using MHD simulations, thereby providing a robust simplified model for flares that can be used in a variety of applications, such as meteo forecasting, generating synthetic data or studying active regions.

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