# Rogue Waves and Intermediate Shock Instability in Alfvenic Turbulence

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The derivative nonlinear Schrödinger (DNLS) equation has been extensively used in space-physics literature to describe the dynamics of weakly nonlinear dispersive Alfvén waves propagating in a direction either parallel or making a small angle with the ambient magnetic field. In the former case, localized solutions vanish at large distance, while the latter condition corresponds to nonzero conditions at infinity. In both cases, the DNLS equation is completely integrable by the inverse scattering transformation. This equation should in fact be viewed as an idealized model, as additional effects, such as a weak dissipation, are usually present and can potentially have a significant dynamical influence.

We previously showed that in the presence of a small enough dissipation, the dynamics of a bright soliton with non-zero boundary conditions leads to a kind of quasi-collapse where, after becoming a breather, the solution can locally reach a larger and larger amplitude and a smaller and smaller width as the dissipation coefficient is reduced, a process that nevertheless requires longer and longer times. Afterward, the soliton is rapidly dissipated with the generation of delocalized small-scale fluctuations. This evolution also leads to the formation of persistent dark solitons, possibly associated with the magnetic holes commonly observed in space plasmas [1].

In order to address the robustness of this process of “rogue wave” formation in a turbulent regime, we have considered the case where the weakly dissipative DNLS equation is randomly driven at large scales [2]. We observed a global evolution that is rather similar to that described above, in the sense that the random fluctuations created at early time by the forcing term rapidly evolve to a quasi-solitonic turbulence where structures of different amplitude move chaotically, interact with each other and merge. From time to time, large solitonic structures develop, whose amplitude oscillates. Such a solution seems locally similar to an oblique breather whose further evolution corresponds to a quasi-collapse, associated with a peak of the energy dissipation. The distribution of the instantaneous global maxima of the AW intensity fluctuations is seen to be accurately fitted by power laws, which contrasts with the integrable regime (absence of dissipation and forcing) where the behavior is rather exponential. As the dissipation is reduced, freak waves form less frequently but reach larger amplitudes. It is of interest to note that such a phenomenon could possibly be related to the short-lived large-amplitude pulsations, usually called SLAMS (for short large-amplitude magnetic structures) observed upstream the quasi-parallel bow shock, that display a strong amplitude enhancement and that can be regarded as solitary waves with an amplitude-dependent propagation speed [3].

It turns out that a regime of strongly intermittent-in-time dissipation also occurs in the absence of dispersion, in the so-called Cohen-Kulsrud equation that describes weakly dissipative Alfvén waves. Like standard MHD, this equation is not strictly hyperbolic and thus displays intermediate shocks associated with a sharp variation of both the amplitude and the direction of the magnetic field. When the angle variation is larger than 180°, these structures are unstable, as the front steepens and the amplitude jump increases up to the formation of a neutral point for the transverse field and a change in the wave polarization. A fast shock is simultaneously emitted, leading the system to relax towards a stable configuration. This process survives in the turbulent regime and is associated with the formation of short peaks of dissipation that contribute to the heating of plasmas such as coronal loops.

## References


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