A chaotic model of Van der Pol oscillations in space and laboratory plasmas

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Van der Pol oscillations are of great interest in laboratory plasma discharges and solar dynamo. We study the nonlinear dynamical behavior of Van der Pol oscillations based on the numerical solutions of the Van der Pol equation. The fundamental properties of complex dynamics of Van der Pol oscillations are characterized which exhibit muiltiscale and multistability behaviors, as well as the coexistence of order and chaos. In particular, we focus on the dynamics and structure of unstable periodic orbits and chaotic saddles within a period window of the bifurcation diagram, at the onset of a saddle-node bifurcation and of an attractor merging crisis, and in the chaotic regions associated with type-I intermittency and crisis-induced intermittency. Inside a periodic window, chaotic saddles are responsible for the transient motion preceding convergence to a periodic or a chaotic attractor. The links between chaotic saddles, crisis and intermittency in space and laboratory plasmas are discussed. We show that a chaotic attractor is composed of chaotic saddles and unstable periodic orbits located in the gap regions of chaotic saddles. Nonlinear modeling of chaotic saddle, crisis and intermittency can improve our understanding of the intermittent plasma turbulence in tokamaks and in basic plasma experiments in laboratory, as well as the dynamics of solar cycle intermittency in the observed time series of sunspot cycles and in the numerical simulations of solar dynamo.