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**Strongly non-linear magnetization dynamics
in nano-structures**
**Perturbations, multi-mode generation, and topological
droplets**

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Strongly non-linear magnetization dynamics in nano-structures. Perturbations, multi-mode generation, and topological droplets

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ABSTRACT

Spin torque oscillators (STOs) are magnetic nano-devices in which strongly non-linear magnetodynamic phenomena can be excited by current. In this thesis, we study some of these phenomena by means of micromagnetic simulations, analytical calculations, and electrical characterization. Three main subjects are discussed:

1. **External perturbations**, which can induce synchronization and modulation. In the former case, STOs are shown to exhibit an under-damped or non-Adlerian behavior, defining a minimum synchronization time. For the latter, slow external sources can induce the so-called Nonlinear Amplitude and Frequency Modulation, from which the modulation bandwidth is defined. Both perturbations can be combined for the technologically relevant case of synchronized and modulated STOs. It is shown that regimes of resonant and non-resonant unlocking exist.
2. **Multi-mode generation** of STOs is described by a novel analytical framework. In particular, the generation linewidth is calculated, and it is shown to be intrinsically related to the coupling between multiple modes. Mode coexistence is found to be analytically possible and, further, observed experimentally and numerically. Electrical characterization of in-house fabricated devices confirms the analytical predictions and suggests the possibility of fine-tuning and controlling spin wave propagation at the nanoscale.
3. **Topological droplets** are numerically shown to exist when the STOs are patterned into nanowires. The following droplet modes have been found: a non-topological edge mode that is attracted by the physical boundaries and increases its footprint to satisfy the damping / spin torque balance, and a topological (chiral) quasi-one-dimensional droplet that can be considered as the dynamical counterpart of breathing soliton-soliton pairs.

Keywords: Spintronics, spin torque oscillators, solitons, injection locking, modulation, multi-mode generation, magnetic droplets, skyrmions.