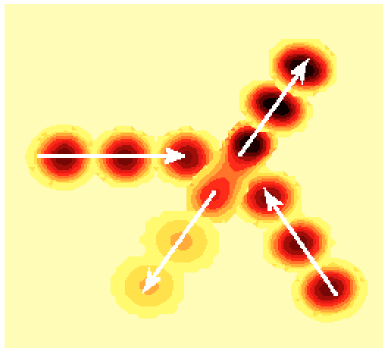
Interactions of two-dimensional magnetic droplet solitons

Author

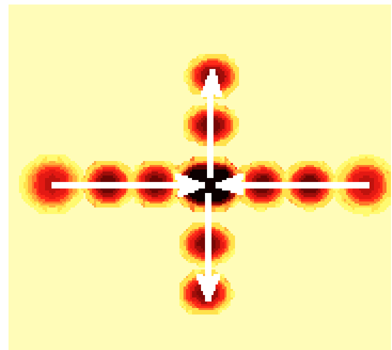
Motivated by recent observations of magnetic droplet solitons [1], this work numerically investigates and classifies interactions of localized, propagating, nonlinear magnetic wave solutions of the Landau-Lifshitz equation. The idealized model studied has perpendicular, easy-axis anisotropy and applies to thin (two-dimensional) magnetic films. In contrast to a previous work that used approximate initial conditions [2], here an existing database of accurately computed solutions [3], or droplets, is utilized to generate precise initial conditions for a micromagnetic solver. Among the interactions explored are two droplets oriented to collide either head-on or at an angle. Parameters varied include the initial droplets' rest frequency, ω, and velocity, $\vec{V}$, as well as the relative phase, $\Delta\phi$, and domain offset, Δy, between the two droplets.

Presented here is a complete classification of two-droplet interactions where the droplets have the same ω and $|\vec{V}|$, but with changes in $\vec{V}$ and $\Delta\phi$ between the two droplets. This leads to 3 broad categories of behaviors largely dependent on $\Delta\phi$: attraction scattering, repulsion scattering, and annihilation. First, two droplets may attract each other, combine, and then split into two new, unequal droplets traveling in opposite directions along $\vec{V_1} + \vec{V_2}$. This is common for small $\Delta\phi$. Second, droplets may repel each other, appearing to reflect off the line the attractive droplets would have traveled (Fig. 1(c)). This is common for droplets with $\Delta\phi$ close to π. Finally, there is a narrow range of $0 < \Delta\phi < \pi$ where the conglomerate and repulsion forces are approximately equal, and the droplets annihilate each other (Fig. 1(d)).

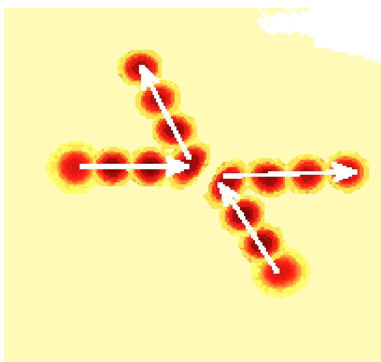
Behaviors seen previously are special cases of these categories. For example, when two in-phase droplets approach each other head-on, two equal-sized droplets are formed, which is the commonly cited 90° scattering behavior [2] (Fig. 1(b)). Since most interactions are a variation of these three interactions, magnetic droplet collisions could be useful for spin-based logic operations.



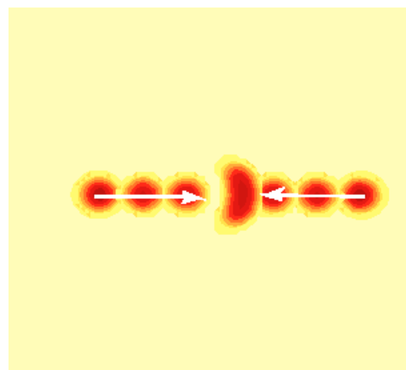
(a) Attraction Scattering



(b) 90° Scattering



(c) Repulsion Scattering



(d) Droplet Annihilation. The droplet disappears after the fourth step shown.

Figure 1: Examples of two-droplet simulations. The arrows show the direction of the droplets' movements as time progresses.

References

[1] S.M Mohseni, S.R. Sani, J. Persson, T.N. Anh Nguyen, S. Chung, Ye. Pogoryelov, P.K. Muduli, E. Iacocca, A. Eklund, R. K. Dumas, S. Bonetti, A. Deac, M.A. Hoefer, and J. Akerman. Spin torque-generated magnetic droplet solitons. *Science*, 339:1295–1298, March 2013.

[2] B. Piette and W.J. Zakrzewski. Localized solutions in a two-dimensional Landau-Lifshitz model. *Physica D*, 119(3):314–326, 1998.

[3] M.A. Hoefer and M. Sommacal. Propagating two-dimensional magnetic droplets. *Physica D*, 241(9):890–901, May 2012.