Demagnetisation energy and magnetisation variation effects on the confined isolated skyrmion state dynamics

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Introduction

- For simplicity, in micromagnetic studies, **demagnetisation** energy contribution is **neglected** and/or **three dimensional samples are modeled using two-dimensional meshes**.

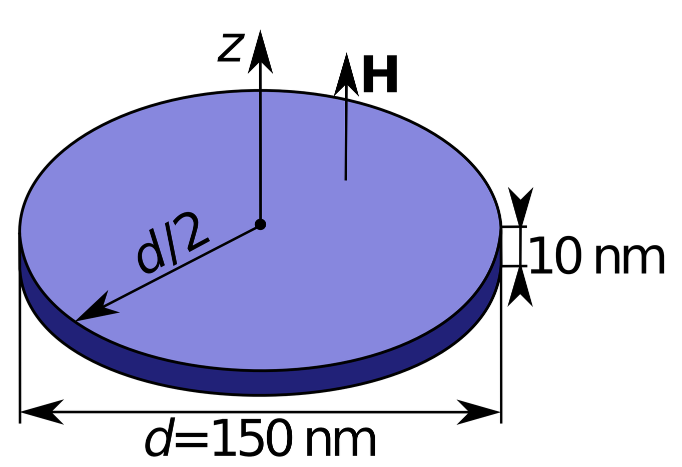
- Recent work [1] demonstrated that using these assumptions is **not justified** when studying the stability of skyrmionic states in confined helimagnetic nanostructures.

- In this work [2], we study whether these model simplifications are justified when **dynamics of skyrmionic states is explored**.

- We demonstrate that although the magnetisation dynamics associated to the eigenmodes do not change significantly, their **frequencies change substantially**.

Methods

- **Geometry** and **material parameters**



FeGe [1]:

M_s = 384 kA/m

A = 8.78 pJ/m

D = 1.58 mJ/m^2

- **Hamiltonian**

$$w = A(\nabla \mathbf{m})^2 + D\mathbf{m} \cdot (\nabla \times \mathbf{m}) - \mu_0 M_s \mathbf{H} \cdot \mathbf{m} + w_d$$

(symmetric exchange; Dzyaloshinskii-Moriya; Zeeman; demagnetisation)

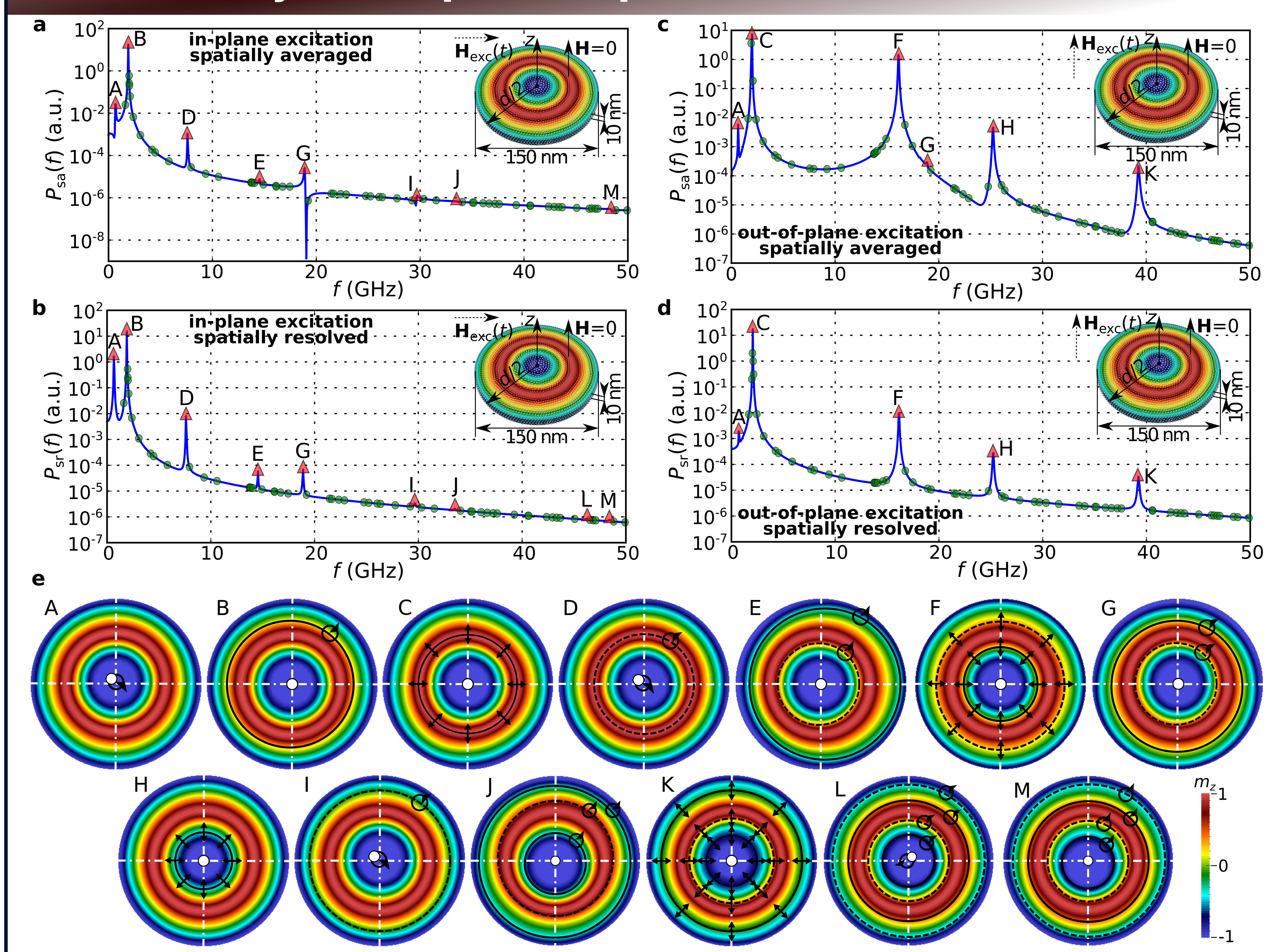
- **Dynamics** (LLG equation)

$$\frac{\partial \mathbf{m}}{\partial t} = -\gamma_0^* \mathbf{m} \times \mathbf{H}_{\text{eff}} + \alpha \mathbf{m} \times \frac{\partial \mathbf{m}}{\partial t}$$

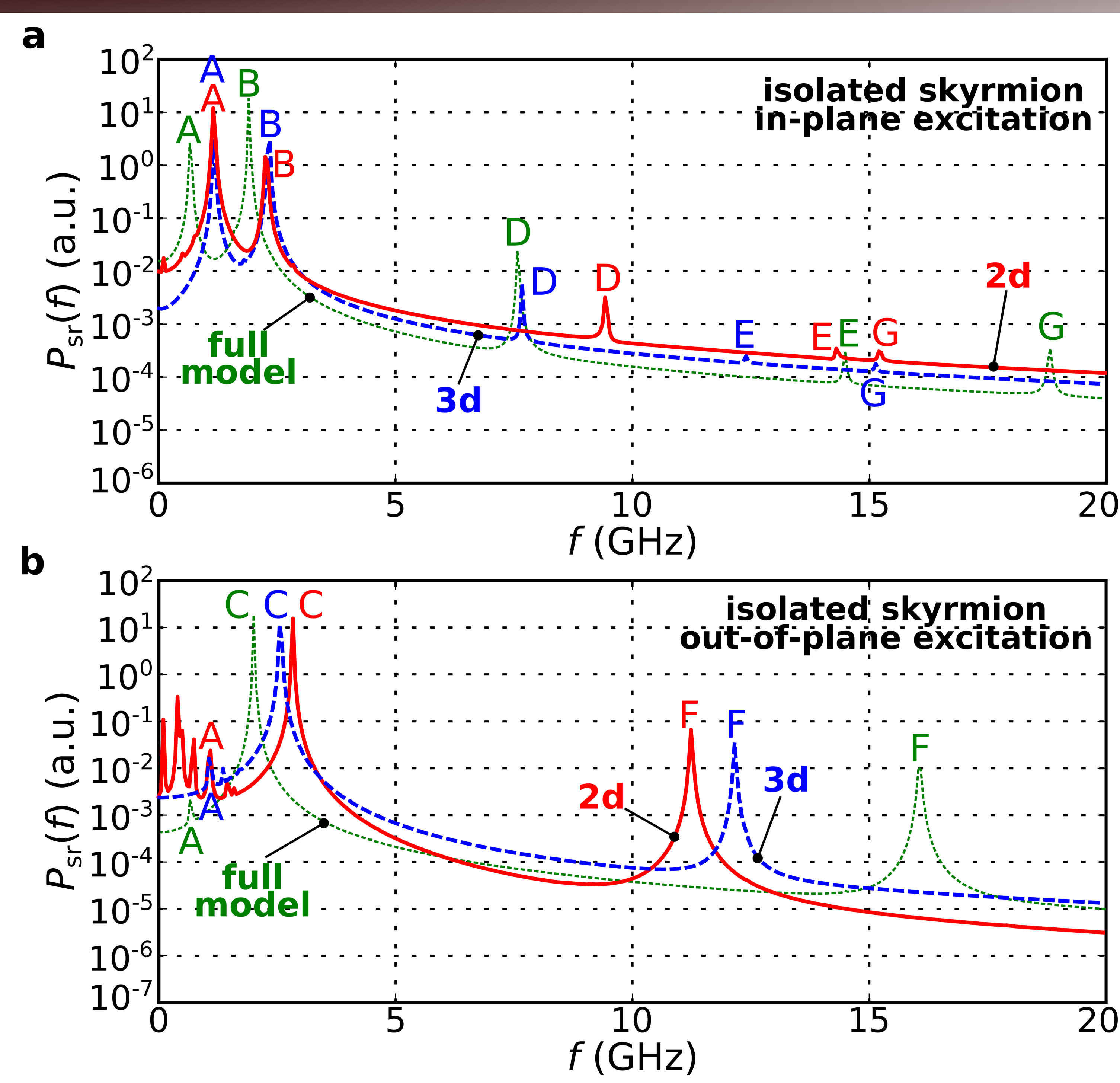
(precession; damping)

- **Full 3D finite elements** simulation model
- **No** assumption about **translational invariance** in the out-of-plane direction
- **Eigenvalue method** [3] allows us to compute all existing eigenmodes
- We perform the **ringdown method** [4] to determine what eigenmodes can be excited using a particular experimentally feasible excitation
- After full 3D ringdown simulations, we (i) artificially **set the demagnetisation energy contribution to zero** and (ii) **model thin film sample using two-dimensional mesh**
- Power spectral densities are computed using **spatially averaged** and **spatially resolved analyses**

Isolated skyrmion power spectral densities



Demagnetisation and magnetisation variation effects



References

[1] Beg, M. et al., *Scientific Reports* **5**, 17137 (2015).
[2] **Beg, M. et al. *Phys. Rev. B* 95 014433 (2017).**
[3] D'Aquino, M. et al., *J. Comput. Phys.* **228**, 6130 (2009).
[4] McMichael, R. D. and Stiles, M. D., *J. Appl. Phys.* **97**, 10J901 (2005).

Conclusion

- Using full three-dimensional model, employing two different methods (eigenvalue and ringdown), we **explored the dynamics** of an isolated skyrmion state.
- By artificially **setting the demagnetisation energy to zero and modeling the three-dimensional thin film sample with two-dimensional mesh**, we computed power spectral densities for an in-plane and an out-of-plane excitations.
- We conclude that although the magnetisation dynamics associated to particular eigenmodes do not change significantly, their **frequencies change substantially**.