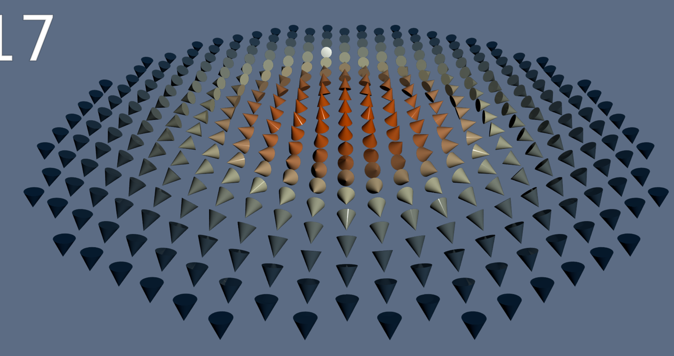
THE SKYRMION PROJECT



Skyrmionics EPSRC Programme Grant Meeting, Warwick 21 -23 March 2017

Computational modeling of skyrmions in magnetic nanostructures

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Research interests

- Software for computational science
- Simulation of nanomagnetic structures
- Doctoral training and best computational practice: better software for better science

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Research interests

- Theory of phase transitions
- Computational modelling
- Inverse problems in magnetism models

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Research interests

- Computational micromagnetics
- Magnetic skyrmions
- Simulation and modelling

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Research Fellow at the University of Southampton since February 2017

Research interests

- Theoretical and experimental aspects of thin film magnetic devices and their applications
- device modeling using atomistic and micromagnetic models

A selection of results on skyrmions

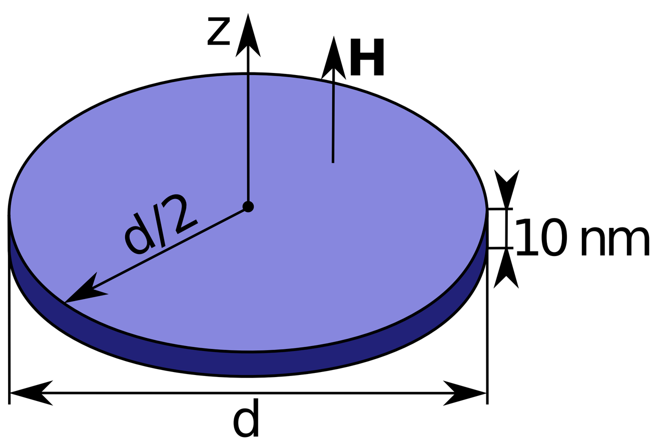
Hysteresis A variety of skyrmion states can be identified in non-centrosymmetric FeGe nanocylinders with thicknesses > 45 nm and a diameter of 150 nm by simulating the hysteresis loop. The demagnetizing field was found to act as the main stabilitzing factor for the skyrmion states (R. Carey et al., APL 109, 122401 (2016)).

Thermal stability The search for the minimum energy path of the skyrmion annihilation in a nanotrack yielded the annihilation at the boundary as the energetically most favorable. This path circumvents the topological protection and comes along with a short lifetime of the skyrmions (D. Cortes-Ortuno et al., arXiv:1611.07079v1 (2016)).

Microwave fields In the presence of symmetry breaking (e.g. by an external magnetic field) a microwave field exerts a net driving force on skyrmions. This force can be used to move skyrmions effectively (W. Wang et al., PRB 92, 020403(R) (2015)).

Dynamics of an incomplete skyrmion state in a nanodisk[1]

Geometry and material parameters[2]:



FeGe:

M_s = 384 kA/m

A = 8.78 pJ/m

D = 1.58 mJ/m^2

Hamiltonian:

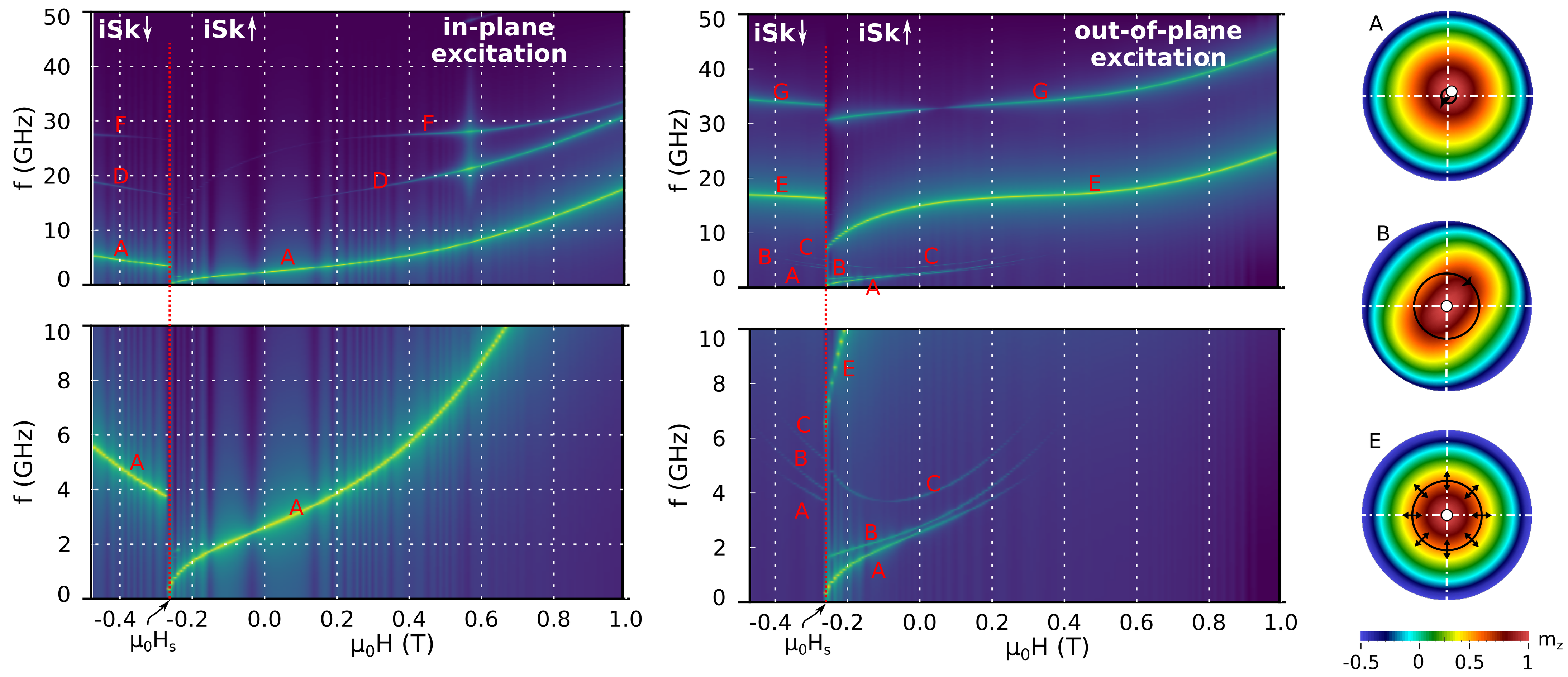
$$w = \underbrace{A(\nabla \mathbf{m})^2}_{\text{symmetric exchange}} + \underbrace{D\mathbf{m}\cdot(\nabla\times\mathbf{m})}_{\text{Dzyaloshinskii-Moriya}} \underbrace{- \mu_0 M_s \mathbf{H}\cdot\mathbf{m}}_{\text{Zeeman}} + \underbrace{w_d}_{\text{demagnetisation}}$$

Dynamics (LLG equation):

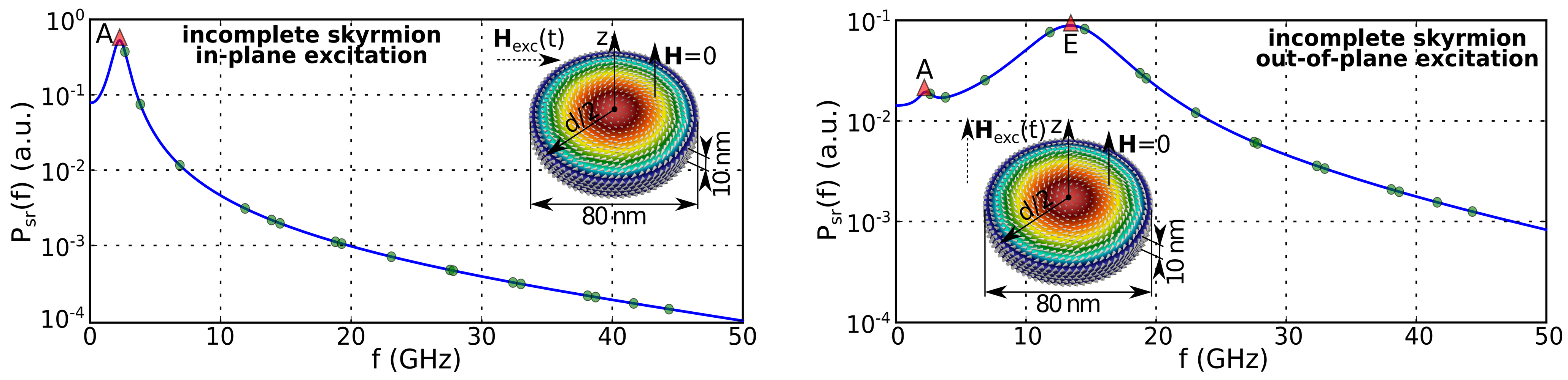
$$\frac{\partial \mathbf{m}}{\partial t} = \underbrace{-\gamma_0^* \mathbf{m}\times\mathbf{H}_{\text{eff}}}_{\text{precession}} + \underbrace{\alpha\mathbf{m}\times\frac{\partial \mathbf{m}}{\partial t}}_{\text{damping}}$$

- **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
- All frequencies in the ringdown method are excited approximately equally in the [0, 100 GHz] range using **cardinal sine wave excitation**

Field dependent power spectral density maps and dominant eigenmodes



Simulation results with experimentally measured damping parameter α = 0.28



[1] Beg, M. et al., Phys. Rev. B **95**, 014433 (2017) [2] Beg, M. et al., Scientific Reports 5, 17137 (2015) [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).

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