# Stable magnetic singularity in helimagnetic nanostructures containing boundary between grains with different chirality

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## Introduction

- Skyrmionic states can be the **ground state** in confined helimagnetic nanostructures in absence of both external magnetic field and magnetocrystalline anisotropy [1, 2].

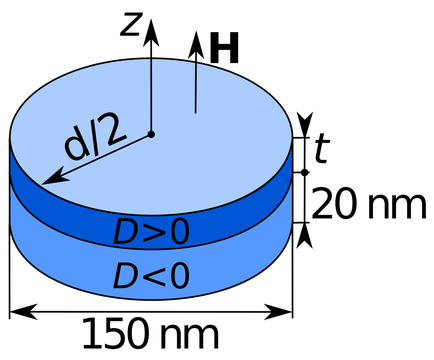
- Skyrmionic ground states emerge in the form of **incomplete Skyrmion (iSk)** and **isolated Skyrmion (Sk)** states [1, 2].

- In this work, we explore what magnetisation configurations emerge if nanostructures contain the **boundary between grains with different chirality**.

- We explore the stability and hysteretic behaviour of **zero-field stable Bloch point** [3, 4, 5] configurations in the studied system using finite elements micromagnetic simulations.

## 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)

**- Skyrmion number**:

$$S = \frac{1}{4\pi t} \int \mathbf{m} \cdot \left( \frac{\partial \mathbf{m}}{\partial x} \times \frac{\partial \mathbf{m}}{\partial y} \right) \mathrm{d}^3 r$$

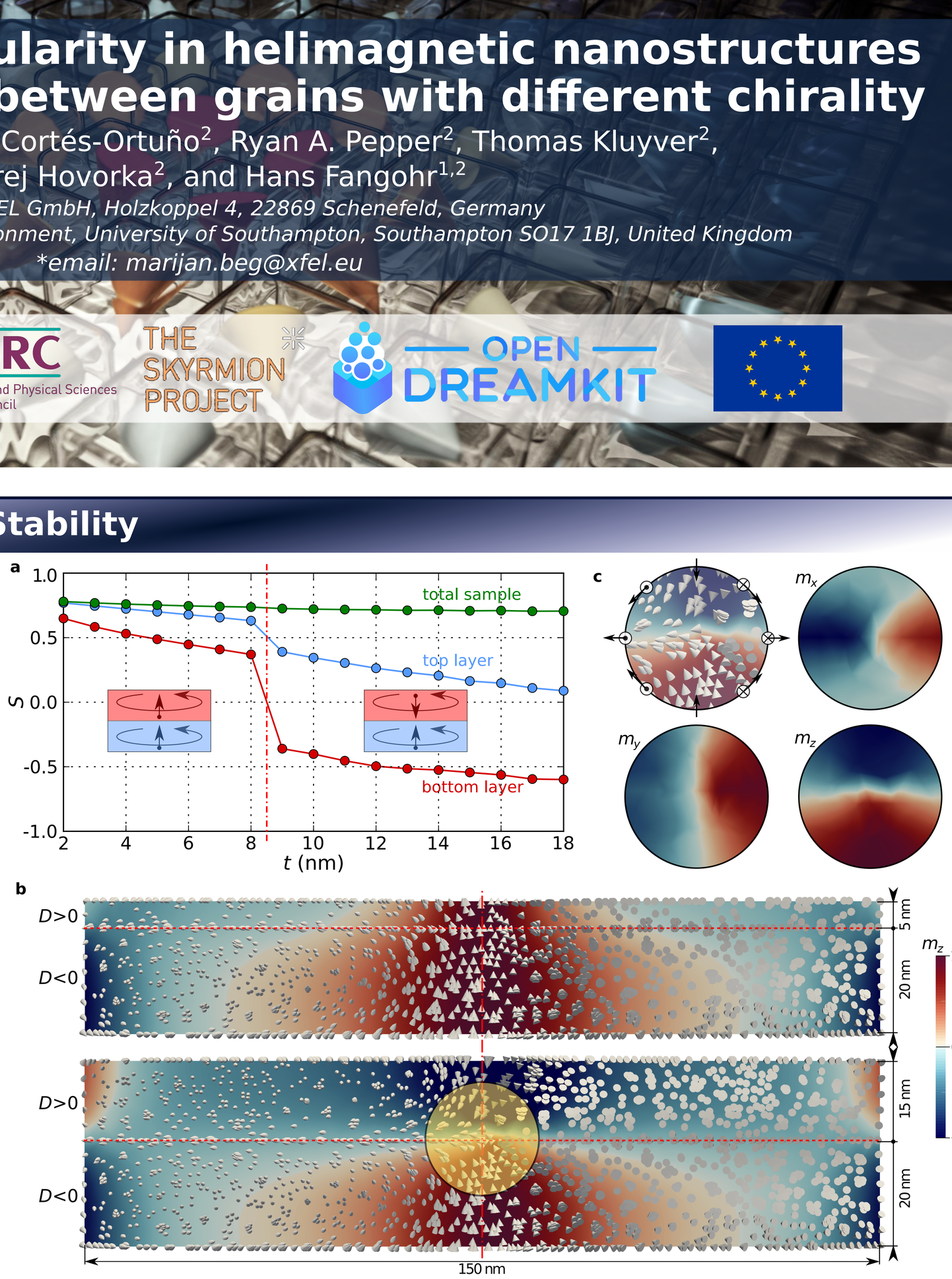
- **Full 3D finite elements** simulation model

- **No** assumption about **translational invariance** in the out-of-plane direction

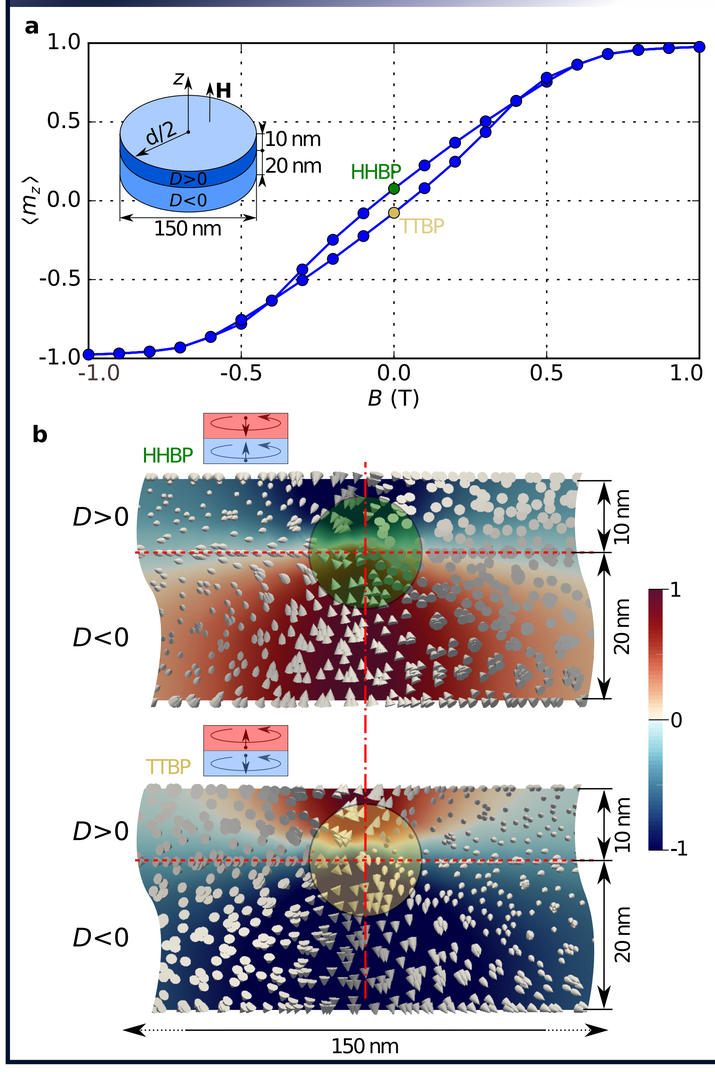
- Full computation of **demagnetisation** energy.

- **Maximum** mesh **discretisation is 3 nm**.

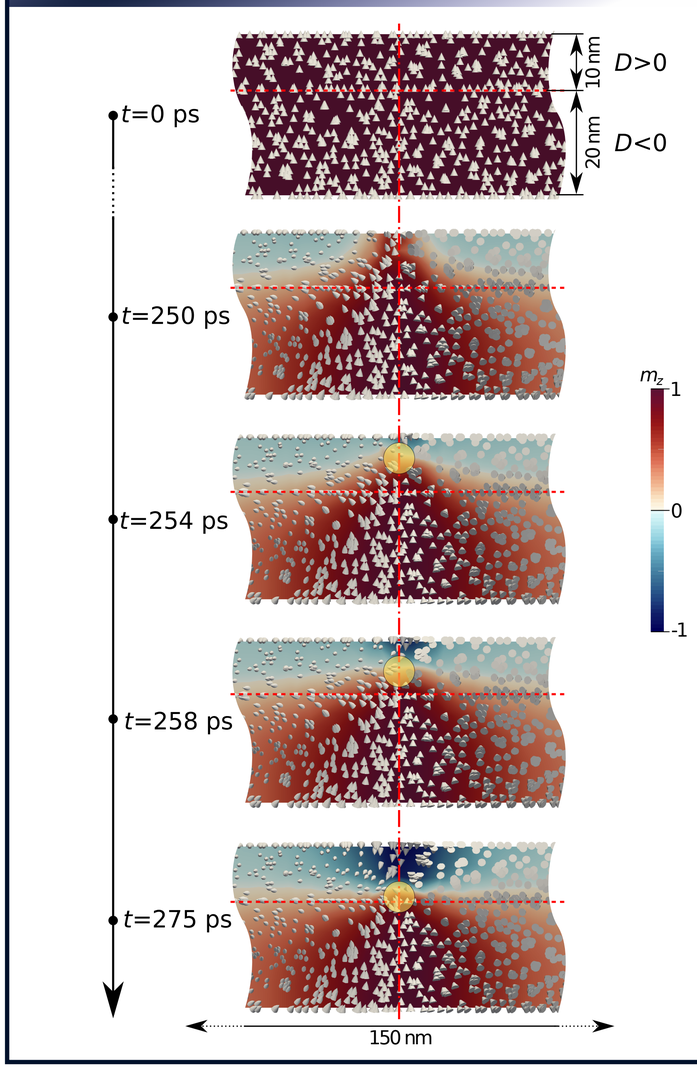
## Stability




## Hysteresis




## Creation




## References

[1] M. Beg et al., *Scientific Reports* **5**, 17137 (2015).
[2] M. Beg et al. *Phys. Rev. B* **95**, 014433 (2017).
[3] E. Feldtkeller. *Z. Angew. Phys.* 19, 530 (1965).
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[5] C. Andreas et al. *J. Magn. Magn. Mater.* **362**, 7 (2014).

## Summary

- We find that the **Bloch point emerges between grains with different chirality**.
- The **Bloch point** is stable at zero external magnetic field.
- We demonstrate the existence of **two different Bloch point configurations** (Head to Head BP and Tail to Tail BP) at zero external magnetic field.
- By exploring hysteretic behaviour, we demonstrate that we can **switch between HHBP and TTBP**.
- Finally, we demonstrate that in the relaxation process, the **BP is created at the boundary**.