



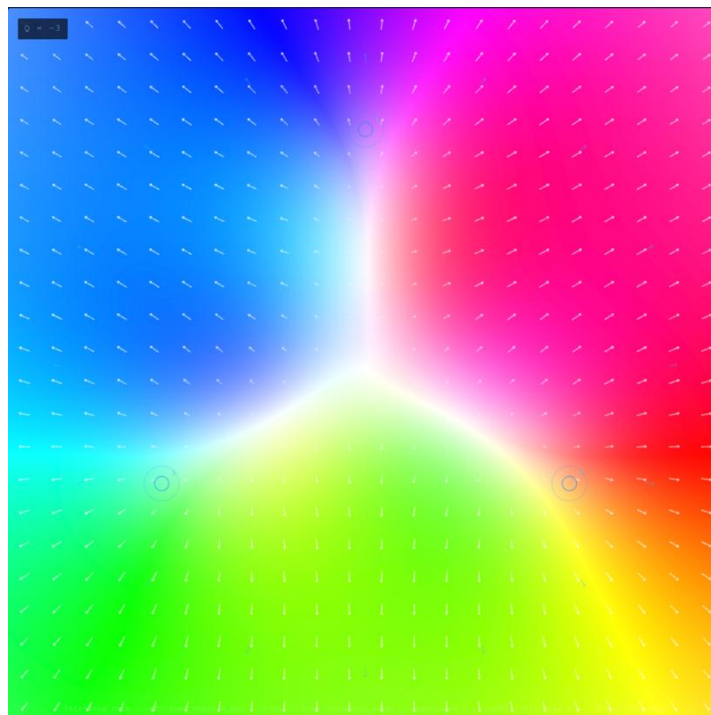
Topological  
Textures in  
Condensed  
Matter

# TOPOLOGY EXPLORER

*A Visual Guide to Magnetic Skyrmions*

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For the Curious — No Physics Background Required



COST Action POLYTOPO — CA23134

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# Part 1 — The Big Idea: Topology Without the Equations

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## 1.1 The Shape That Cannot Become a Ball

Here is a puzzle: take a doughnut and a coffee mug. To a mathematician, they are the same object. Both have exactly one hole — the doughnut's central opening and the mug's handle — and you could, in principle, squish one into the other by stretching and kneading, without ever tearing or drilling. A ball is a different matter entirely. It has zero holes, and no amount of squeezing will give it one.

This is topology in a nutshell: the study of properties that survive any smooth deformation. Bending, twisting, and stretching are all allowed. Tearing and gluing are forbidden. The number of holes is a topological property. So is the winding number — how many times a curve loops around a central point. These numbers are always whole integers, and they cannot change unless something breaks.

### □ Why Integers Matter

Topological quantities come in discrete steps: 0, 1, 2, 3... You cannot have 0.7 holes in a doughnut. This discreteness is what makes topological objects so resilient: a small disturbance cannot nudge a winding number from 1 to 0.99. It would have to jump the full integer gap — which costs a huge amount of energy.

## 1.2 Spin — Every Electron Is a Tiny Compass

Every electron in a material behaves like a microscopic bar magnet. Physicists call this property its spin, and it has a direction: it points somewhere in 3D space. In an ordinary fridge magnet, almost all the spins point in the same direction, like a crowd of tiny compass needles that all agree to face north.

Now imagine a material where the spins refuse to agree. Instead, they arrange themselves into an intricate, ordered swirl — a pattern with a well-defined winding number, called the topological charge  $Q$ . Once the spins have settled into a configuration with  $Q = -1$ , they are locked in. The winding cannot undo itself without a dramatic, energy-costly event. The spin pattern becomes, in a very real sense, topologically protected.

### 1.3 Meet the Skyrmion

A **magnetic skyrmion** is the most celebrated topological spin texture. Named after British physicist Tony Skyrme, who predicted similar objects in nuclear physics in the 1960s, skyrmions were first spotted experimentally in 2009. They were so tiny and so stable that physicists immediately started imagining them as data bits — the smallest possible magnetic switches.

Here is what a single skyrmion looks like as you travel outward from its centre:

- **At the core** — the spin points straight down (into the material).
- **Halfway out** — the spins lie flat, pointing outward or curling around (depending on the type).
- **Far from the core** — the spins flip back to point uniformly upward, the background state.

This gradual rotation from down to up, as you travel outward, wraps the unit sphere exactly once. The topological charge is  $Q = -1$ . It cannot smoothly relax to the uniform background ( $Q = 0$ ) without crossing a substantial energy barrier — which is the origin of its remarkable stability.

#### □ A Quick Note on 'Topological Protection'

In real materials, skyrmions can still be created and destroyed — at sample edges, under strong currents, or via exotic defects. 'Protection' means an enhanced energy barrier, not absolute immortality. Think of it as a very tall wall, not an unbreakable one.

### 1.4 A Family of Topological Textures

Texture	What makes it special
<b>Skyrmion (<math>Q = -1</math>)</b>	Spins wrap the unit sphere once. Found in chiral magnets like MnSi and $\text{Fe}_{0.5}\text{Co}_{0.5}\text{Si}$ . The workhorse of the field.
<b>Antiskyrmion (<math>Q = +1</math>)</b>	Opposite-handed winding. Coexists with skyrmions in $D_2$ d-symmetry magnets like $\text{Mn}_{1.4}\text{PtSn}$ — same energy, opposite charge.
<b>Magnetic vortex (<math>Q \approx 0</math>)</b>	Planar in-plane winding. Core polarity (up/down) and chirality (CW/CCW) are independent degrees of freedom.
<b>Hopfion</b>	A 3D soliton with non-zero Hopf index. Cross-sections reveal nested toroidal spin loops — each field line is a closed curve linked with others.

## 1.5 Reading the Colour Wheel

Throughout this guide — and throughout the scientific literature — spin textures are visualised with a colour-wheel colourmap. Every pixel carries precise physical meaning:

- **Hue** (red, green, blue...) encodes the in-plane spin direction. Think of it as a compass rose: East → red, South → yellow-green, West → cyan, North → blue-violet.
- **Full colour saturation** means the spin lies completely in-plane.
- **White** means the spin points straight up — the background state ( $s_z = +1$ ).
- **Dark / near-black** means the spin points straight down — the skyrmion core ( $s_z = -1$ ).

### □ The Colour Wheel Test

A single skyrmion produces a complete rainbow ring around its core. As you travel around the core, the in-plane spin rotates a full  $360^\circ$ , cycling through every colour. If you see a complete colour wheel — that's  $Q = -1$ . If the wheel is reversed — that's  $Q = +1$  (an antiskyrmion). A double rainbow ring means  $Q = -2$ .

## Part 2 — Why Does It Matter?

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### 2.1 From Lab to Storage Device

A skyrmion is 1–100 nanometres across — roughly 1,000 times smaller than a human hair. It is stable, it has a well-defined position, and it can be **pushed along a magnetic wire by a tiny electric current**. This makes it a candidate for racetrack memory: information encoded as the presence (1) or absence (0) of a skyrmion at a position on a nanoscale wire, streaming past a read head at high speed.

Because topology protects each skyrmion from scattering off the defects that plague conventional magnetic domain walls, far less current is needed to drive them. The device would be faster, denser, and far more energy-efficient than anything available today. The 2026 research frontier focuses on room-temperature stability, materials diversity, and device integration in 2D magnets and van der Waals heterostructures.

### 2.2 Beyond Magnetism

Topological textures appear far beyond magnetic materials. The same mathematical structure turns up in:

- **Liquid crystals** — toron structures with Hopf index, visible under polarised light.
- **Cold-atom clouds** — skyrmions in Bose-Einstein condensates, observed since 2009.
- **Photonics** — optical skyrmions in structured light and evanescent fields.
- **Neuromorphic computing** — skyrmions as artificial synapses, with position encoding synaptic weight.

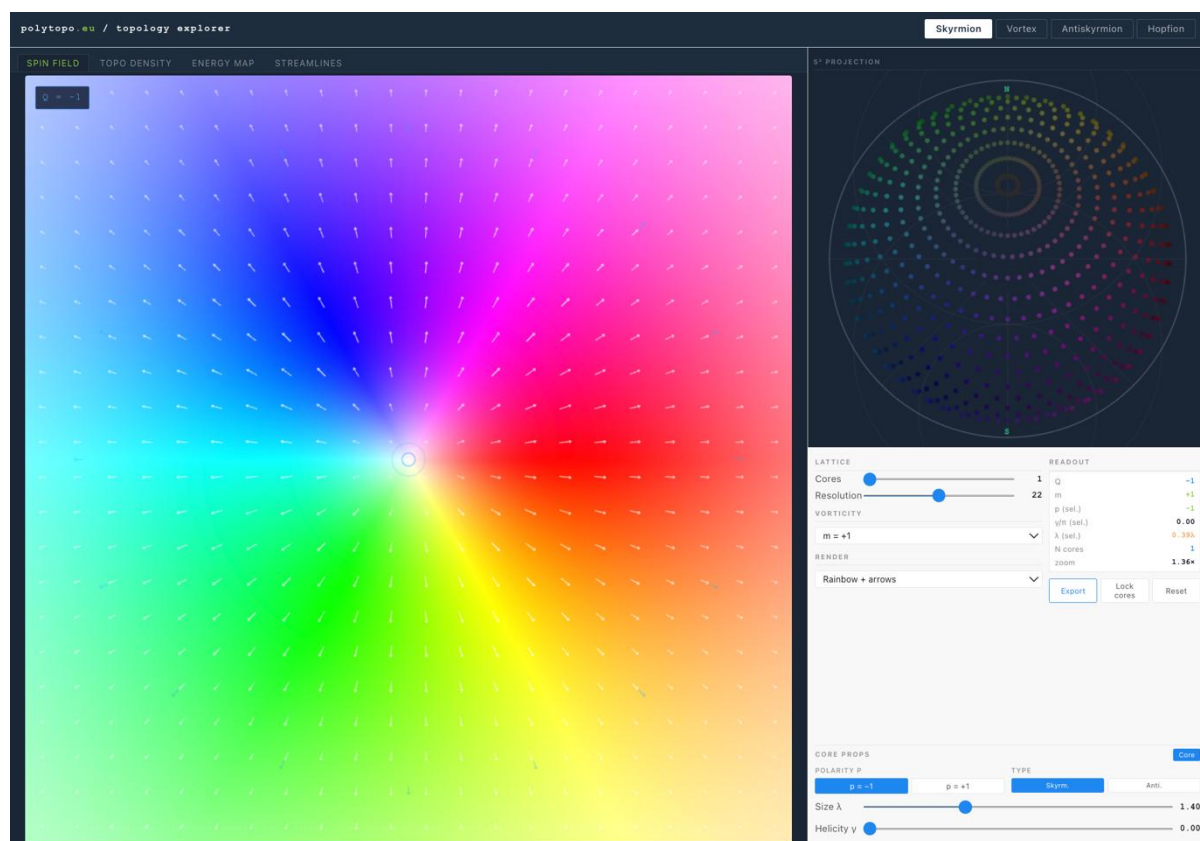
The Explorer focuses on magnetic textures, but the intuition you build here carries directly into all of these fields.

# Part 3 — The Explorer at a Glance

## 3.1 Layout

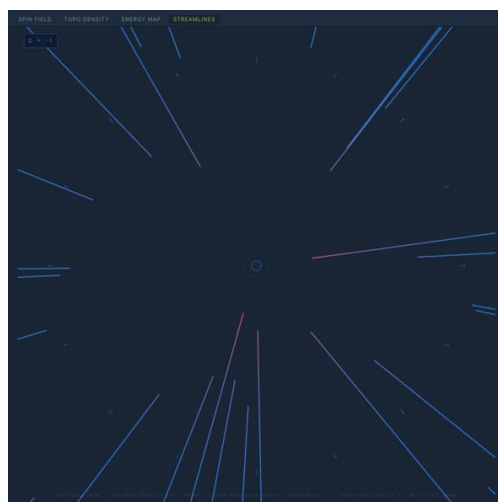
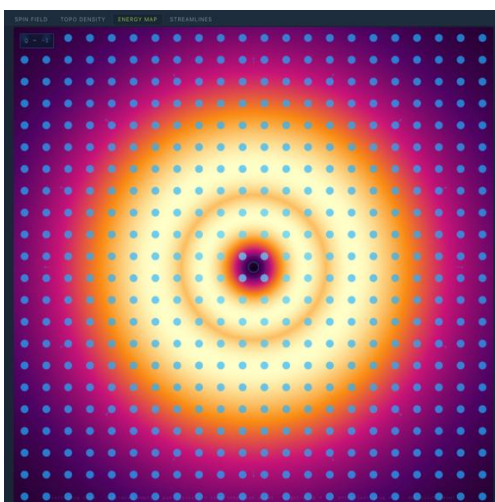
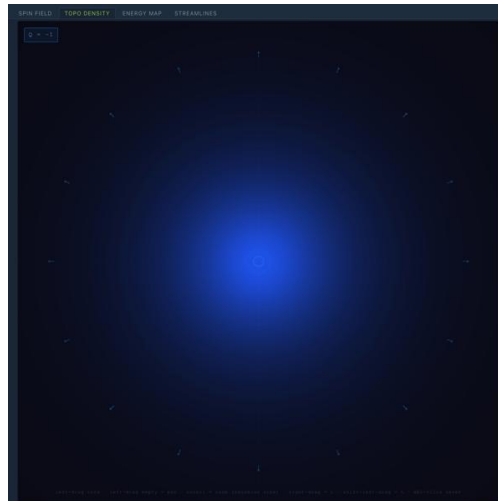
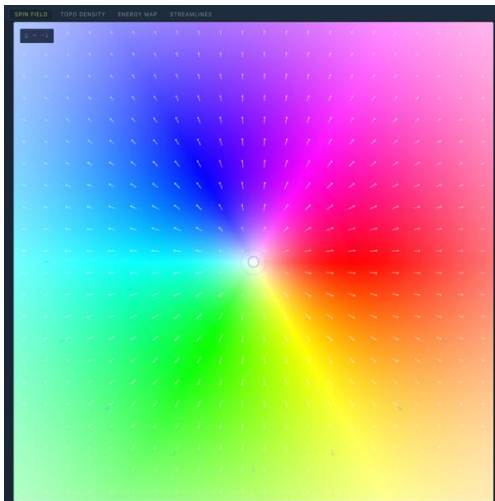
When you open the Explorer at [polytopo.eu/topology-explorer](http://polytopo.eu/topology-explorer) you see four main areas:

Area	What it does
Mode tabs (top bar)	Switch between Skyrmion, Antiskyrmion, Vortex, and Hopfion. Sets the type for all cores — overrideable per core.
Main canvas (large, left)	The interactive spin texture display. Four view tabs sit above it.
$S^2$ sphere (top right)	Maps every spin in the texture onto the unit sphere. Watch it change as you add cores or adjust helicity.
Controls (bottom right)	Sliders, readout panel, and per-core properties. Shown controls change with the active view tab.



## 3.2 The Four Views

View tab	What you see
Spin field	Arrows and/or colour map of spin directions. Use the Render dropdown to switch between colourmap styles, arrow overlays, or the 3D hedgehog.
Topo density	Pixel heatmap of topological charge density $\rho(r)$ . Integrating over the full plane gives the integer $Q$ .
Energy map	Local magnetic energy. J, D, and K sliders appear here to tune exchange, DM interaction, and anisotropy. Colour is on a fixed scale set by the sliders themselves, so brightness is directly comparable as you move cores, resize skyrmions, zoom, or pan.
Streamlines	Field lines following the in-plane spin component. Shows winding character clearly — Néel gives radial lines, Bloch gives rings.



### 3.3 Canvas Controls

Action	Effect
<b>Left-drag near a core ring</b>	Move that core. Also selects it in the Core props panel.
<b>Left-drag on empty canvas</b>	Pan the entire spin texture.
<b>Scroll wheel</b>	Viewport zoom — the canvas scales like a map: skyrmions appear larger/smaller and core markers move with the field. Does not change any physical property of the skyrmion.
<b>Right-drag horizontally</b>	Rotate helicity $\gamma$ of the selected core continuously.
<b>Shift + left-drag vertically</b>	Physically resize $\lambda$ (the core radius) of the nearest or selected core.
<b>Double-click</b>	Quick reset: restores pan, zoom, and core positions. Sliders unchanged.
<b>Reset button</b>	Full reset: all sliders, mode, view, and per-core properties return to defaults.
<b>Lock cores button</b>	Move the entire core formation as a rigid group.

### 3.4 Per-Core Properties

Each core has independently adjustable properties in the Core props panel beneath the sliders. Select a core by clicking C1 / C2 / C3 / C4, or by clicking or dragging a core on the canvas.

Property	What it controls
<b>Polarity p</b>	$p = -1$ : core spin points down (default). $p = +1$ : points up. Changes the energy landscape but not Q.
<b>Type</b>	Skyrmion ( $Q = -1$ ) or Antiskyrmion ( $Q = +1$ ) — overrides the global mode tab for this core only.
<b>Size <math>\lambda</math></b>	Radius of the spin profile. Drag the slider, click the label to type, or Shift + left-drag on the canvas.
<b>Helicity <math>\gamma</math></b>	Orientation of in-plane spins. $\gamma = 0$ : Néel (radial). $\gamma = \pi/2$ : Bloch (curling). Click the label and type $\pi/2$ for an exact value.
<b>Apply to all cores</b>	Copies this core's $\lambda$ , $\gamma$ , polarity, and type to every other core in one click.

The screenshot shows the 'CORE PROPS' panel for core C1. It features two tabs: 'POLARITY P' and 'TYPE'. Under 'POLARITY P', there are two buttons: 'p = -1' (highlighted in blue) and 'p = +1'. Under 'TYPE', there are two buttons: 'Skyrm.' (highlighted in blue) and 'Anti.'. Below these are two sliders: 'Size  $\lambda$ ' with a value of 1.40 and 'Helicity  $\gamma$ ' with a value of 0.00. At the bottom, there is a button labeled 'Apply to all cores'.

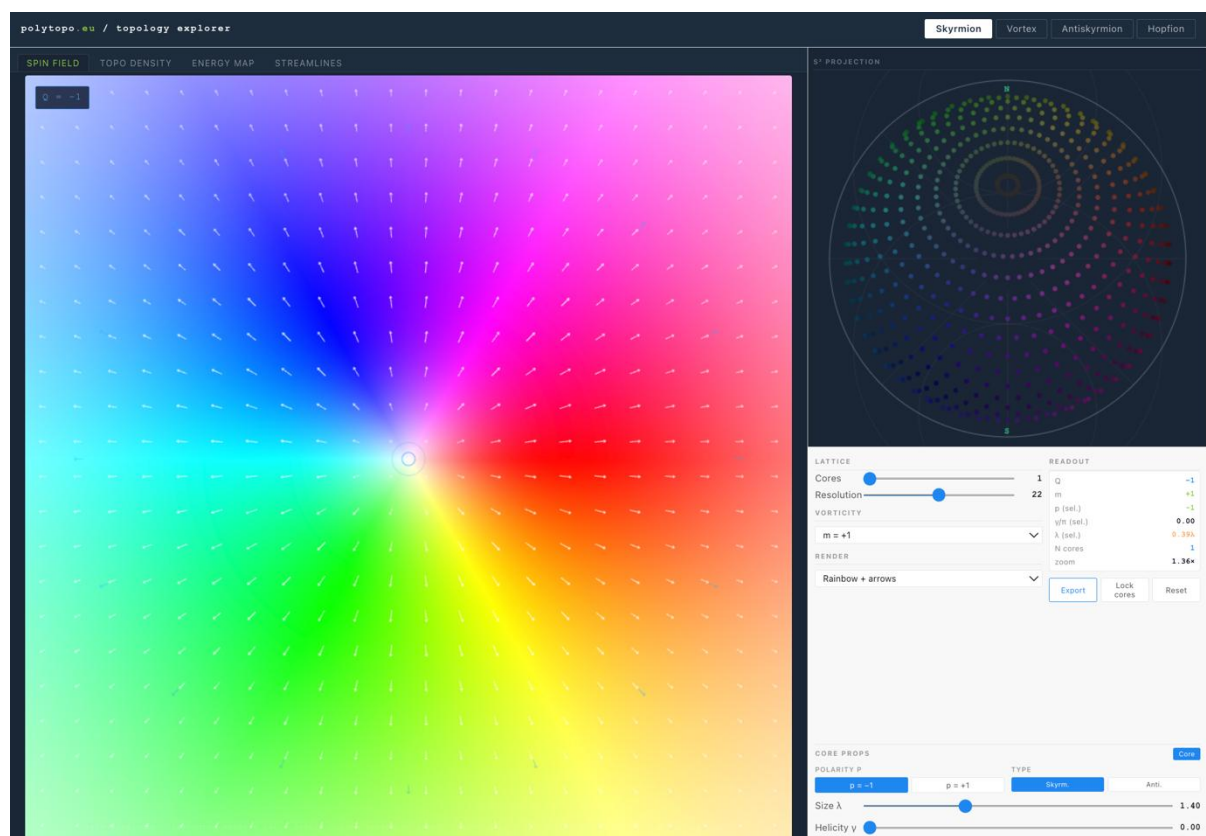
# Part 4 — Step-by-Step Explorations

The four explorations below are ordered from simplest to most advanced. Click Reset before each one to start from a clean state.

## Exploration 1 Your First Skyrmion

This is the default view when you open the Explorer — no setup needed. Arrows radiate outward from a dark centre in a perfect starburst. Each colour tells you which direction that spin points in the plane. This is exactly how skyrmions are visualised in published scientific papers.

Mode tab	Skyrmion
View tab	Spin field
Render	Rainbow + arrows
Cores	1
Core → Size $\lambda$	1.40
Core → Helicity $\gamma$	0.00 (Néel — spins point radially outward)
Core → Polarity $p$	-1



## What to observe

- The colour cycles through the full rainbow as you travel around the core — this is the complete  $360^\circ$  winding of the in-plane spin. East = red; South = yellow-green; West = cyan; North = blue-violet.
- The dark spot at the centre is the core: the spin there points straight down ( $s_z = -1$ ).
- The  $S^2$  projection panel shows the unit sphere covered exactly once, confirming  $Q = -1$ .
- Left-drag the core anywhere on the canvas. The colour wheel moves with it — and  $Q$  stays at  $-1$  throughout. This is **topological protection** in action: the winding number cannot change just because you moved things around.

### □ Try This: The Bloch–Néel Switch

Click the Helicity  $\gamma$  value label in the Core props panel and type  $\pi/2$  then press Enter. The starburst transforms into a swirl — you have just transitioned from a Néel skyrmion (radial spins) to a Bloch skyrmion (curling spins).

Check the Readout panel:  $Q$  is still  $-1$ . Helicity is a 'soft' degree of freedom — it can change freely while  $Q$  remains the protected quantity.

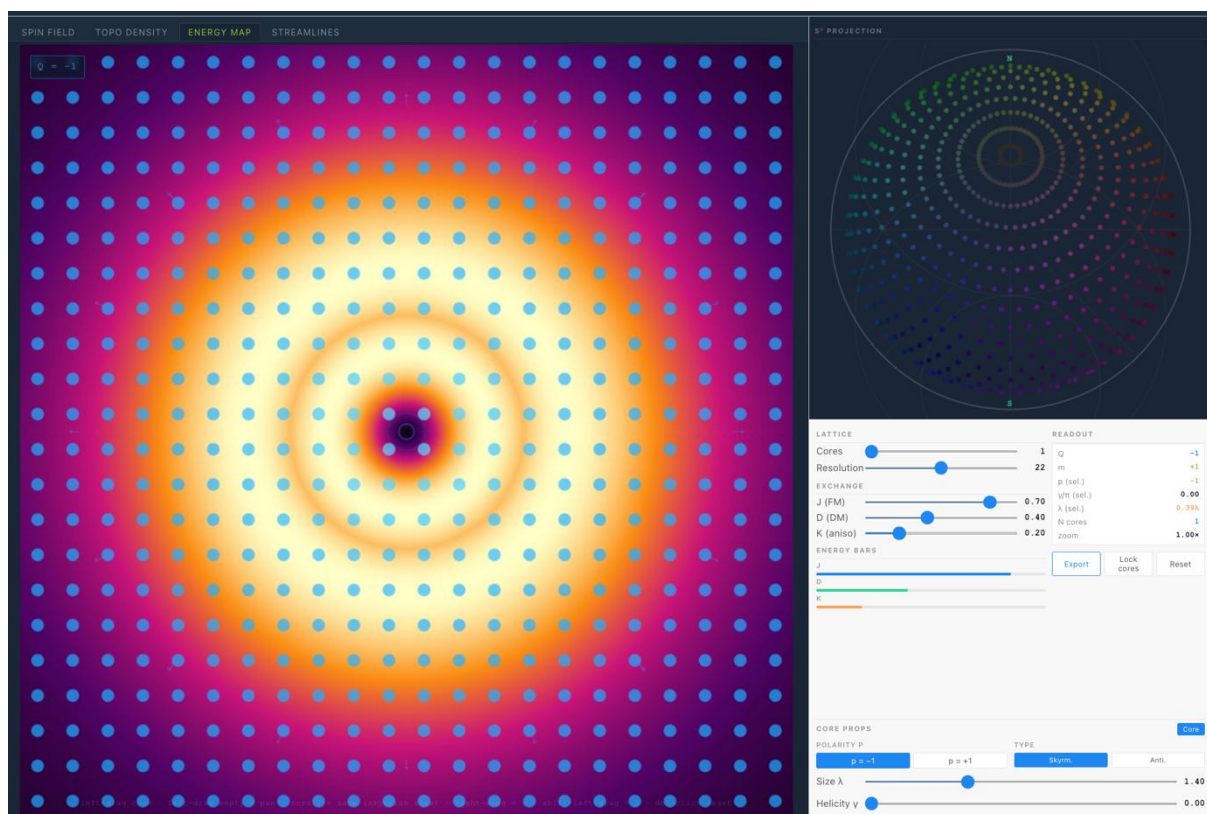
Now type  $0$ ,  $\pi/2$ ,  $\pi$ ,  $3\pi/2$ , and  $2\pi$  in turn and watch the colour wheel make four quarter-turns. At  $2\pi$  you are back where you started.

## Exploration 2

## The Energy Landscape

Where is the energy stored inside a skyrmion? This exploration introduces the Energy map view, which shows where magnetic energy is concentrated. The J, D, and K sliders appear only in this view, letting you tune the three competing interactions that stabilise real skyrmions.

<b>Mode tab</b>	Skyrmion
<b>View tab</b>	Energy map
<b>Cores</b>	1
<b>Core → Size <math>\lambda</math></b>	1.40
<b>Core → Helicity <math>\gamma</math></b>	0.00
<b>J (FM exchange)</b>	0.70 (default)
<b>D (DM interaction)</b>	0.40 (default)
<b>K (anisotropy)</b>	0.20 (default)



### What to observe

- **The energy concentrates in the transition zone** where spins rotate from core to background. Look closely: with the default sliders there are two bright rings separated by a dimmer ring exactly where the spins lie in-plane ( $r \approx \lambda$ ). The exchange and anisotropy energies peak on that in-plane circle, but the DM energy vanishes

there and peaks on either side of it — the competition between the three terms is visible as this double-ring structure.

- Drag **J to +1.0**. The dimmer in-plane ring fills in and brightens — exchange penalises any deviation from alignment most strongly where spins lie fully in-plane, so a strong ferromagnet merges the double ring into one.
- Drag **D to 0.80**. The double-ring structure sharpens: the two DM rings dominate and the dip between them deepens. In real materials, a stronger DM interaction stabilises wider winding and larger skyrmions.
- Reset J and D, then drag **K to 0.80**. The in-plane ring brightens, just as with J — in this map, anisotropy and exchange penalise the same tilted spins. Their difference in real materials lies in the gradient: exchange punishes rapid rotation, anisotropy punishes tilt itself.

□ **Switch to Topo density after this**

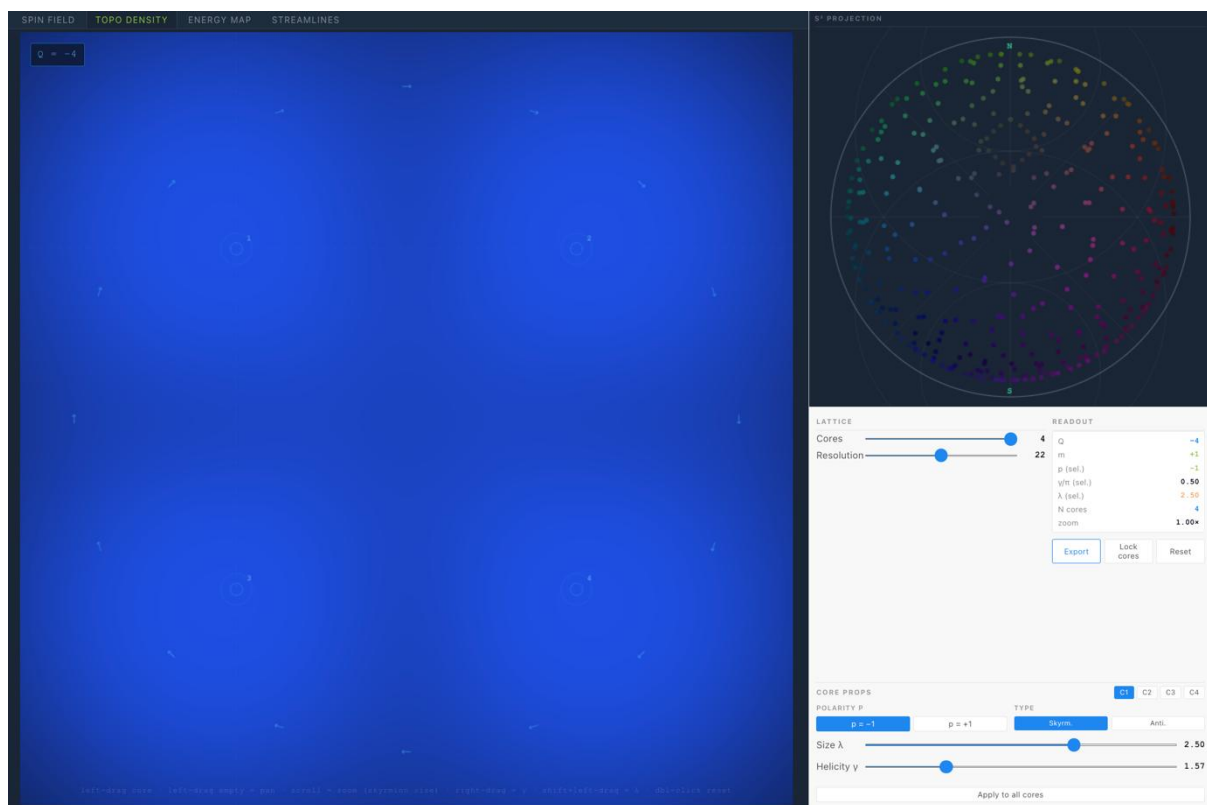
Switch View to Topo density. The topological charge density is concentrated at the core — not in the transition ring. This is a key insight: topological charge is a winding property, not an energy property. The energy ring and the charge density sit in different places.

## Exploration 3

## A Skyrmion Lattice

At low temperatures and the right applied field, skyrmions self-organise into a regular hexagonal lattice — a grid of topological particles. This exploration simulates that with four cores and introduces the Lock cores feature for moving a formation as a rigid group.

Mode tab	Skyrmion
View tab	Topo density
Cores	4
All cores → Size $\lambda$	2.50 (use Apply to all cores)
All cores → Helicity $\gamma$	1.57 ( $\pi/2$ — Bloch type)
All cores → Type	Skyrmion
Resolution	28



### Step by step

1. Set Cores to 4. The four cores appear in a symmetric arrangement.
2. In the Core props panel, set C1 →  $\lambda = 2.50$  and  $\gamma = 1.57$ , then click Apply to all cores.
3. Switch View to Topo density. You now see four charge-density peaks — one per core. The Readout shows  $Q = -4$ .

4. Drag two cores close together. Where the textures overlap, the charge densities merge and distort. Notice that the total  $Q$  stays at  $-4$ .
5. Click Lock cores. Now drag any core — the entire formation moves as a rigid group.
6. Switch View to Spin field with Rainbow (phi-hue) render. The colour wheels of all four cores are visible simultaneously.
7. Click Unlock cores. Pull individual cores apart to explore asymmetric arrangements.

□ **Watch the  $S^2$  sphere**

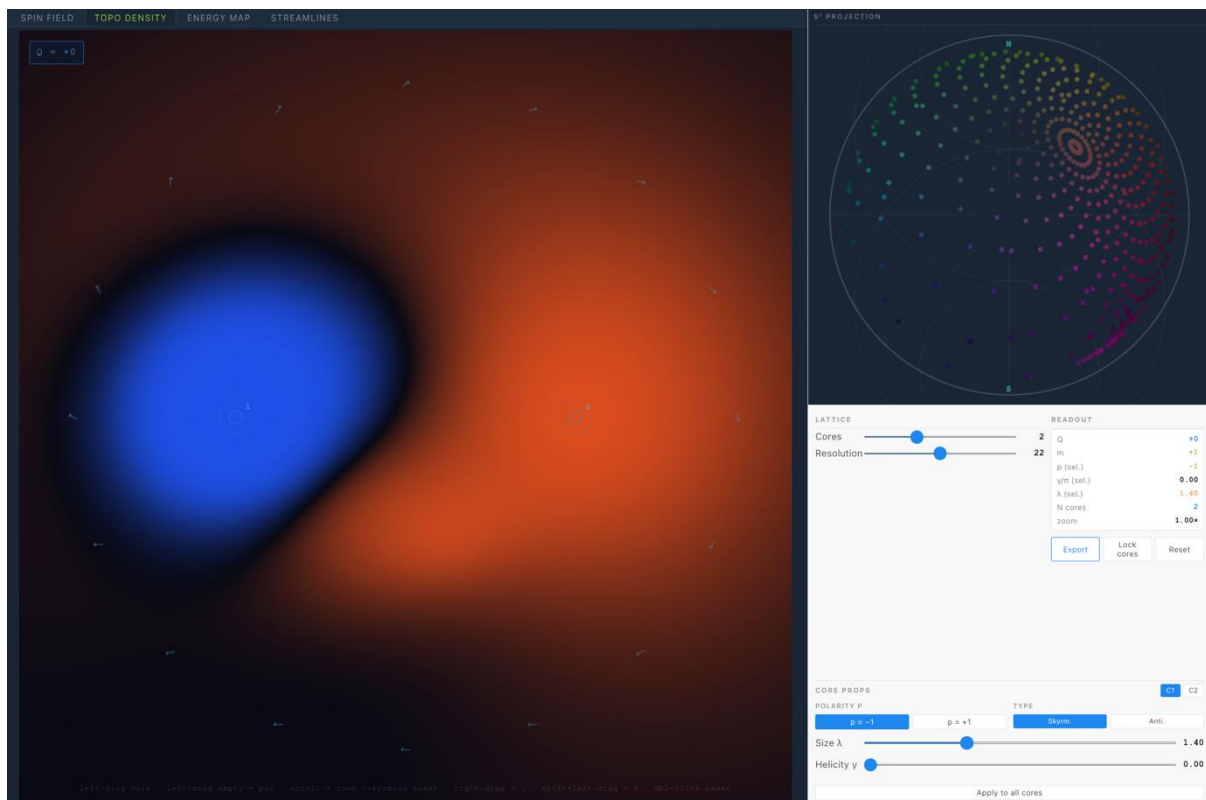
While in locked-formation mode, pan the lattice across the canvas. The  $S^2$  projection stays constant — because you have only shifted the location of the texture, not changed any of its internal spin directions. The sphere always maps what the spins are doing, not where they are.

## Exploration 4

## When Opposites Meet

What happens when a skyrmion ( $Q = -1$ ) and an antiskyrmion ( $Q = +1$ ) share the same material? In certain real materials — such as  $\text{Mn}_{1-x}\text{PtSn}$  with its  $D_2$  d crystal symmetry — both can coexist. This exploration lets you visualise their opposing topological charges and watch them begin to cancel when they approach each other.

<b>Mode tab</b>	Skyrmion (starting point)
<b>View tab</b>	Topo density
<b>Cores</b>	2
<b>Core 1 → Type</b>	Skyrmion ( $Q = -1$ )
<b>Core 1 → Helicity <math>\gamma</math></b>	0.00 (Néel)
<b>Core 1 → Polarity <math>p</math></b>	-1
<b>Core 2 → Type</b>	Antiskyrmion ( $Q = +1$ )
<b>Core 2 → Helicity <math>\gamma</math></b>	1.57 ( $\pi/2$ )
<b>Core 2 → Polarity <math>p</math></b>	-1



## Step by step

1. Set Cores to 2. Both start as Skyrmions.
2. Click C2 to select Core 2. In the Core props panel click the Antiskyrmion type button. The Readout now shows  $Q = 0$ .
3. Set Core 2  $\rightarrow$  Helicity  $\gamma$  to 1.57 by clicking the value label and typing  $\pi/2$ .
4. In Topo density view: Core 1 shows a cool blue charge-density peak ( $Q = -1$ ); Core 2 shows a warm orange peak ( $Q = +1$ ). They are opposite in sign.
5. Drag the two cores close together. Watch the charge densities partially cancel where the textures overlap.
6. Switch View to Spin field with Rainbow + arrows render. Core 1 shows a Néel starburst; Core 2 shows an anisotropic pattern. **Antiskyrmions are not simply rotated skyrmions** — they have a fundamentally different in-plane symmetry.

**The opposing winding patterns are immediately visible: for Néel type ( $\gamma = 0$ ) one core radiates field lines outward while the other draws them inward; switch helicity to  $\gamma = \pi/2$  (Bloch) and one core swirls clockwise while the other swirls counter-clockwise.**

### □ What just happened?

In a real material, if a skyrmion and an antiskyrmion meet, they annihilate — releasing their combined energy as a burst of spin waves. The Explorer models static textures, not dynamics, but watching the charge densities cancel makes the physics visceral.

The antiskyrmion pattern (Core 2) looks genuinely different from a rotated skyrmion. This is why antiskyrmions require a specific crystal environment ( $D_2$  d symmetry) to be energetically stable — the crystal anisotropy has to match the texture's internal symmetry.

## Part 5 — Seven More Things to Try

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Each experiment below takes two to five minutes. Click Reset before each one.

### 5.1 The Bloch–Néel Sweep

*Skyrmion · Spin field · Rainbow + arrows · 1 core*

In the Core props panel, slowly drag the Helicity  $\gamma$  slider from 0 all the way to 6.28 (that is  $2\pi$ ). Watch the colour wheel rotate continuously as the skyrmion passes through every possible helicity: Néel, Bloch, reverse-Néel, reverse-Bloch, and back to Néel. The arrows rotate in sync.  $Q$  stays pinned at  $-1$  throughout the entire sweep.

#### □ What this shows

Helicity is a continuous degree of freedom — like the angle of a compass needle. Topological charge  $Q$  is a discrete, protected quantity — like the number of loops in a knot. In some frustrated magnets, different skyrmions in the same sample can have different  $\gamma$  values, making helicity a new information-carrying degree of freedom independent of  $Q$ .

### 5.2 Per-Core Helicity Disorder

*Skyrmion · Spin field · Rainbow (phi-hue) · 4 cores*

Select each core in turn and set:  $C1 \rightarrow \gamma = 0$ ,  $C2 \rightarrow \gamma = \pi/2$ ,  $C3 \rightarrow \gamma = \pi$ ,  $C4 \rightarrow \gamma = 3\pi/2$ . Each core now shows a distinct  $90^\circ$  colour-wheel rotation relative to its neighbour.

Now switch View to Topo density. The charge distribution looks identical for all four cores. Topology does not depend on helicity — the winding is the same, only the in-plane orientation differs.

### 5.3 Topological Annihilation

*Skyrmion · Topo density · 2 cores · C1: Skyrmion, C2: Antiskyrmion*

Place the two cores far apart (Readout:  $Q = 0$ ). Drag them slowly towards each other. Watch the cool blue ( $Q = -1$ ) and warm orange ( $Q = +1$ ) charge-density peaks approach and cancel. This gives a vivid sense of what topological annihilation means energetically, even though the Explorer models static textures, not dynamics.

## 5.4 S<sup>2</sup> Coverage and the Sign of Q

*Skyrmion · Spin field · 1 core*

Observe the S<sup>2</sup> projection panel. Switch Mode to Antiskyrmion — the sphere coverage reverses orientation (still covered once, but opposite-handed), giving  $Q = +1$ . This reversal is the geometric definition of the sign of  $Q$ .

Now set Cores to 3 (all Skyrmions) — the sphere is covered three times. Switch one core to Antiskyrmion in the Core props panel: coverage partly unwinds and  $Q$  drops to  $-2$ .

## 5.5 Hopfion Cross-Section and Streamlines

*Hopfion · Streamlines · 1 core*

A hopfion is a 3D topological soliton. The Explorer shows a 2D cross-section. In Streamlines view, the nested loop structure is most apparent: field lines form closed rings. The linking of these loops is the Hopf index — a topological invariant for 3D textures, distinct from  $Q$ .

Scroll to zoom into the toroidal core region (or increase Core → Size  $\lambda$  to 2.50 to expand the profile). Then switch View to Spin field with Rainbow (phi-hue) render to see the toroidal winding of the in-plane spin.

## 5.6 Asymmetric Lattice and Interactive Resizing

*Skyrmion · Energy map · 4 cores*

Set Core 1 →  $\lambda = 0.60$  (tiny). Set Core 2 →  $\lambda = 2.50$  (large). Leave Cores 3 and 4 at 1.40. Each contributes a differently-sized energy peak. Click Core 1 on the canvas to select it, then use Shift + left-drag vertically to resize it interactively while watching the energy landscape update in real time.

## 5.7 The 3D Hedgehog View

*Skyrmion · Spin field · Solid hedgehog · 1 core*

The canvas shows a 3D perspective cone plot of the spin texture. Red cones point up (background spins,  $s_z = +1$ ); blue cones point down (core spins,  $s_z = -1$ ); short sideways cones at the transition ring lie in-plane. Left-drag to orbit — drag horizontally to rotate, vertically to tilt. Scroll to zoom.

Try Cores = 2 and drag the cores apart to see two separate hedgehog structures. This view makes it immediately clear why these textures are called hedgehogs in the physics literature.

# Quick Reference

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## Controls at a Glance

Action	Effect
Left-drag core	Move that core (also selects it in Core props)
Left-drag canvas	Pan the spin texture
Scroll	Viewport zoom — skyrmions appear larger/smaller, core markers move with the field. No physical effect on the skyrmion.
Right-drag	Sweep helicity $\gamma$ of the selected core
Shift + drag up/down	Grow / shrink core radius $\lambda$ (physical resize)
Double-click	Reset geometry; sliders unchanged
Reset button	Full reset to factory defaults
Lock cores	Move all cores as one rigid group
Apply to all cores	Copy selected core's properties to all others
Click a value label	Type an exact value (supports pi or $\pi$ notation)

## Colour Encoding

Colour / appearance	Physical meaning
Bright, fully saturated	Spin lies in-plane ( $s_z \approx 0$ )
White	Spin points straight up — background ( $s_z = +1$ )
Black / very dark	Spin points straight down — core ( $s_z = -1$ )
Red	In-plane spin pointing East (right)
Yellow-green	In-plane spin pointing South (down)
Cyan	In-plane spin pointing West (left)
Blue-violet	In-plane spin pointing North (up)
Complete colour ring	One full 360° winding — $ Q  = 1$

# Glossary

Term	Definition
<b>Anisotropy (K)</b>	Preference of spins to align along a specific axis. Competes with exchange to set the skyrmion profile width.
<b>Antiskyrmion</b>	Topological spin texture with opposite-handed winding to a skyrmion; $Q = +1$ in this guide. Stabilised in $D_2$ d-symmetry magnets such as $Mn_{1-x}Pt_xSn$ .
<b>Bloch skyrmion</b>	Skyrmion where in-plane spins curl tangentially around the core. Helicity $\gamma = \pi/2$ .
<b>Chiral magnet</b>	A magnet lacking mirror symmetry, enabling the DM interaction that twists spins into helical patterns and stabilises skyrmions.
<b>Click-to-type</b>	Click any slider value label to type an exact number. Supports pi or $\pi$ notation (e.g. $\pi/2$ , $3*\pi$ ).
<b>DM interaction (D)</b>	Dzyaloshinskii–Moriya interaction — an antisymmetric exchange coupling that favours perpendicular spin pairs and drives helical winding.
<b>Exchange (J)</b>	Quantum-mechanical tendency of neighbouring spins to align ( $J > 0$ , ferromagnetic) or anti-align ( $J < 0$ , antiferromagnetic).
<b>Helicity (<math>\gamma</math>)</b>	Angle specifying the in-plane spin orientation relative to the radial direction. $\gamma = 0$ : Néel; $\gamma = \pi/2$ : Bloch. Independently settable per core in the Explorer.
<b>Hopfion</b>	A 3D topological soliton characterised by the Hopf index — the linking number of closed field-line loops.
<b>Néel skyrmion</b>	Skyrmion where in-plane spins point radially outward from the core. Helicity $\gamma = 0$ (or $\pi$ for inward-pointing variant).
<b>Polarity (p)</b>	Direction of the core spin: $p = -1$ means the core points down (into the material); $p = +1$ means up. Affects energy but not $Q$ .
<b><math>S^2</math> sphere</b>	The unit sphere. A skyrmion maps its surrounding plane onto $S^2$ by wrapping it exactly once — this wrap count defines $Q$ .
<b>Skyrmion</b>	A non-trivial magnetic spin texture with integer topological charge. Convention in this guide: $Q = -1$ .
<b>Spin</b>	The intrinsic angular momentum of an electron, making it behave like a tiny bar magnet with a direction in 3D space.
<b>Topological charge (Q)</b>	An integer winding number counting how many times the spin field wraps the unit sphere. Cannot change without crossing an energy barrier.
<b>Topological protection</b>	Enhanced stability arising from non-trivial topology — a high energy barrier to changing $Q$ . Not absolute immunity in real finite samples.
<b>Vorticity (m)</b>	Winding number of the in-plane spin component around the core. $m = +1$ for a standard skyrmion; $m = -1$ for an antiskyrmion.