Skyrmion

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Outline

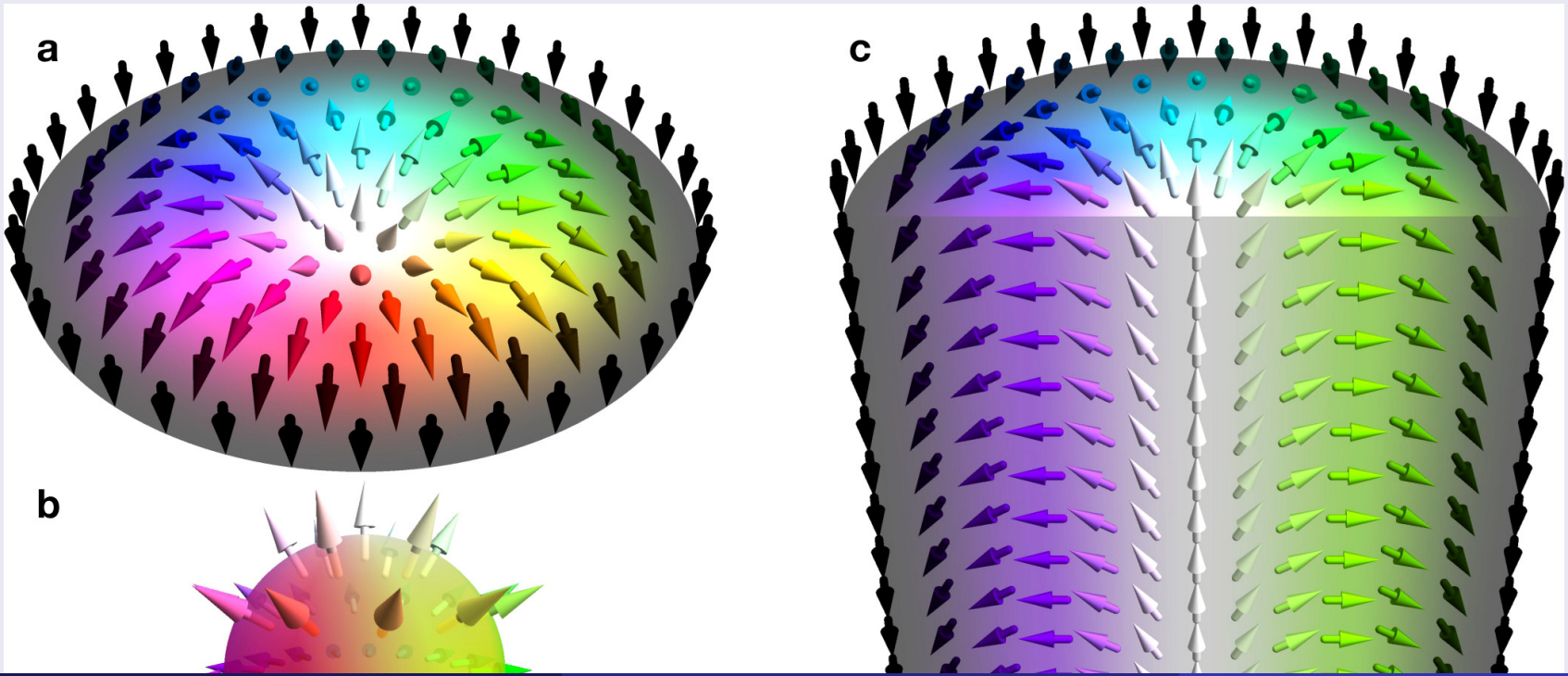
What is *Skyrmion*?

In *Field theory* Skyrmions are the topological stable solution of the non-linear sigma model.

Sigma Model is a field theory that describes the field as a point particle that can move on a manifold

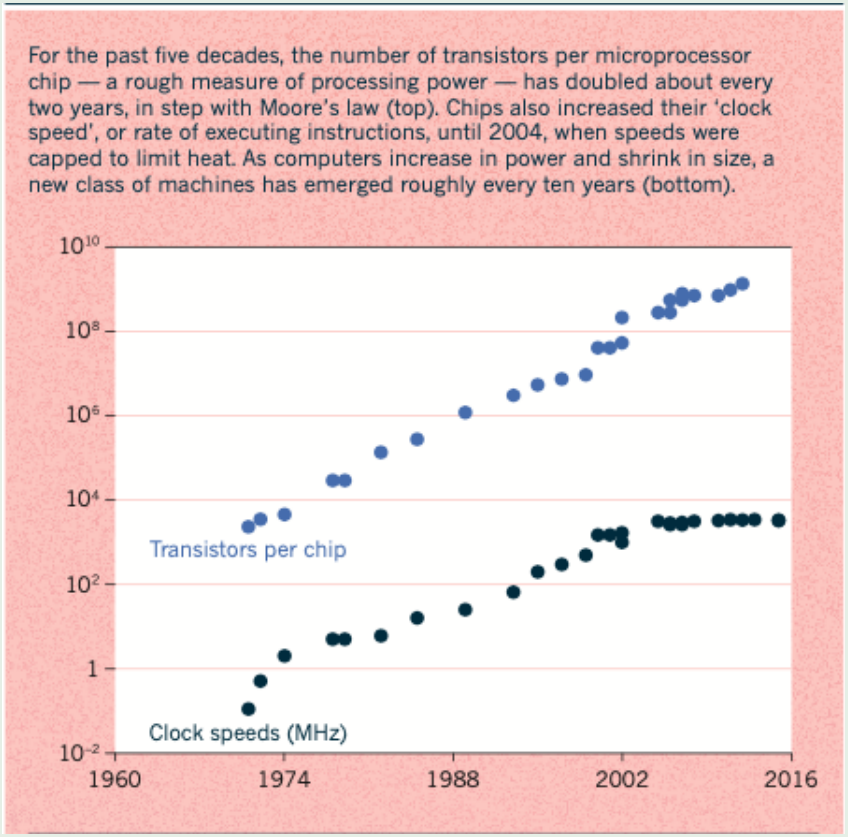
What is a magnetic *Skyrmion*

In condensed matter physics Skyrmions are the two dimensional object which can be exteneded in the third dimensions trivially. For magnetic Skyrmions the direction of magnetization is opposite on the boundary compared to the center of the structure.

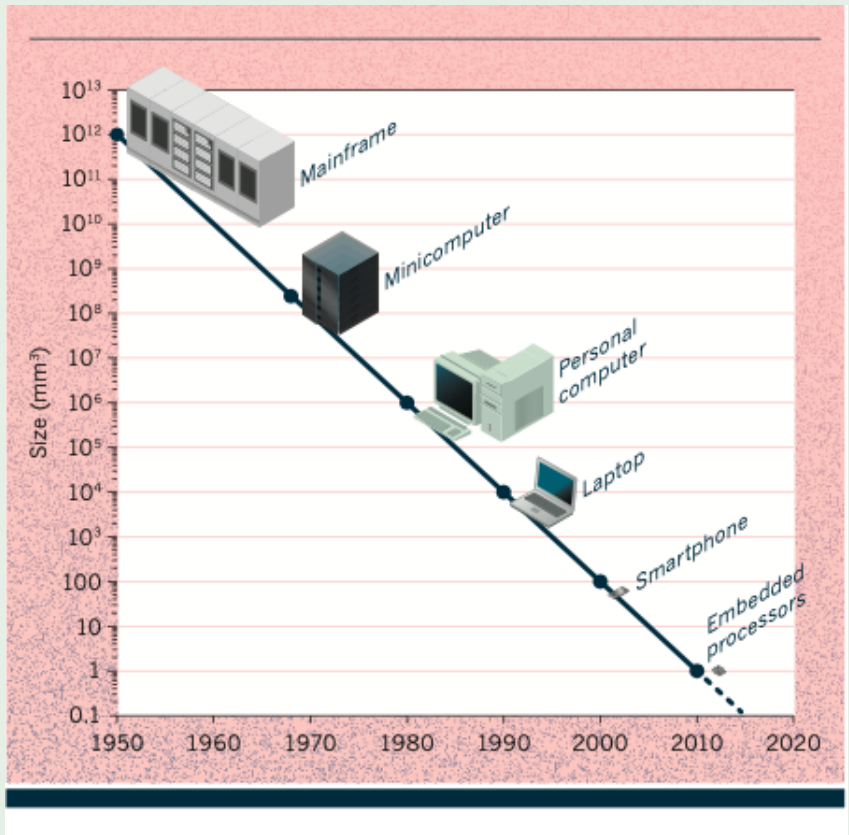


Moore's Law had break down in early 2000s due to *heating* of the sigle core processors.

Example (Transistor on chip)



Example (New systems)



Why *Magnetic Skyrmions* are important?

Two adopted solution to tackle the chip heating problem :

- An upper limit to the clock rates — how fast the microprocessor executes the instruction
- Each chip contains more than one core (processor)

These solutions are not enough now

- In early 2020s the Moore's Law ceased to be satisfied due to quantum effects arising in the circuits. Hence one can not use the simple ballistic transport regime of electrons to represent the bits.

Three solutions are available:

- Milivolts switch
  - Use electron spin states to represent the bits. It is known as milivolts switch.
- 3D stacking of transistors in the processors
- Integration of processors and the memory units on the same chip

Magnetic Skyrmions fits the bill

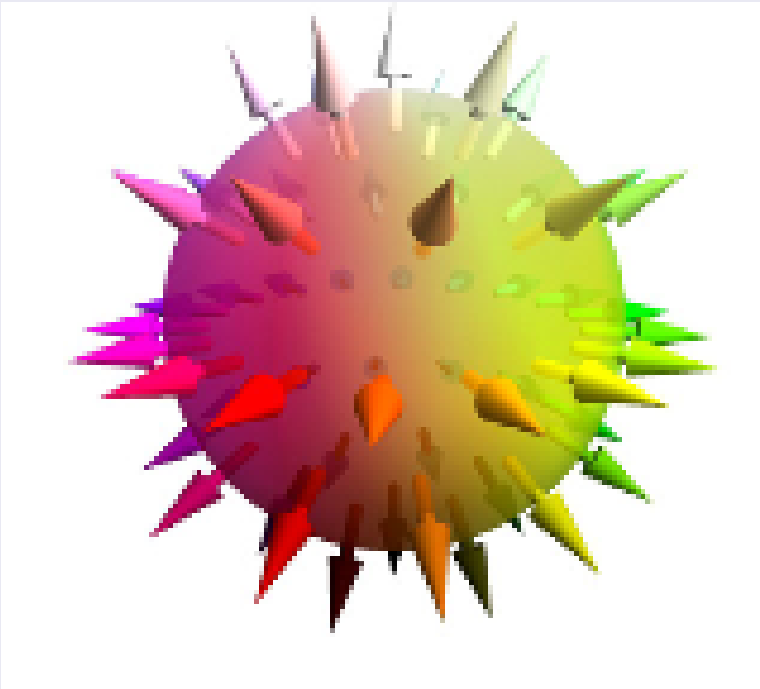
Magnetic Skyrmions are one of the promising candidate for data storage as:

- Their structure depends on electronic spin
- Highly stable due to topological protection

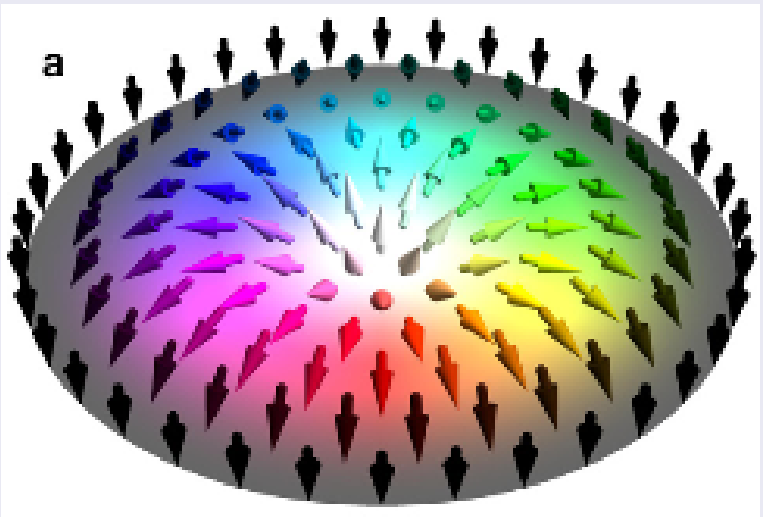
Skyrmion based race track memory device

Topology and characterization of Skyrmion

Bloch sphere



Magnetic skyrmions



Topology

Topological charge

$$N_{sk} = \int n_{sk} d^2 r \tag{1}$$

Toplogical charge density

$$n_{sk} = \frac{1}{4\pi} \mathrm{m}(r) \cdot \left[\frac{\partial \mathrm{m}(r)}{\partial x} \times \frac{\partial \mathrm{m}(r)}{\partial y} \right];$$

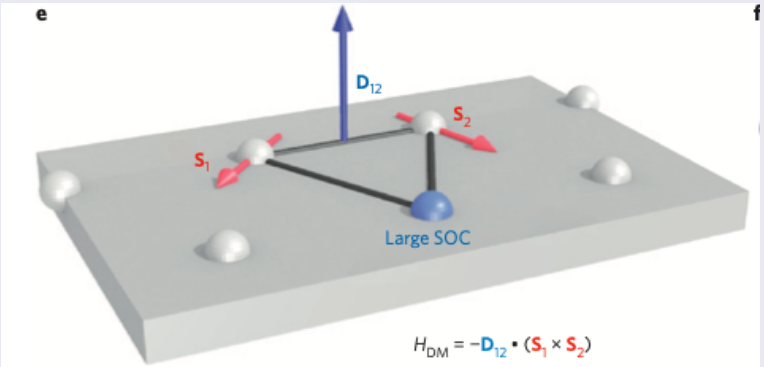
$$\mathrm{m}(r) = m_x(r)\hat{x} + m_y(r)\hat{y} + m_z(r)\hat{z}. \tag{2}$$

In terms of spherical coordinates it can be represented as

- Polarity
- Vorticity

Stabilizing Mechanisms

Dzyaloshinskii–Moriya interaction



Dipole-Dipole interactions