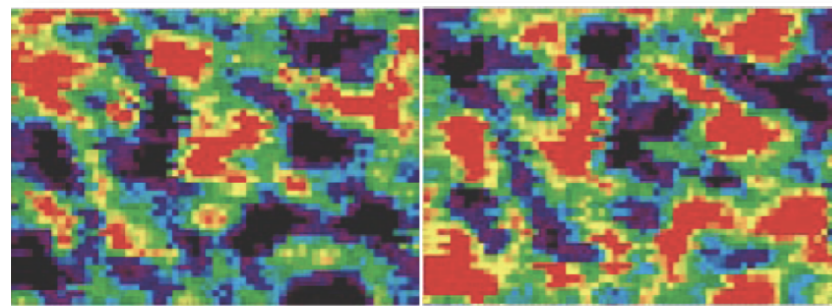


Chiral Magnets

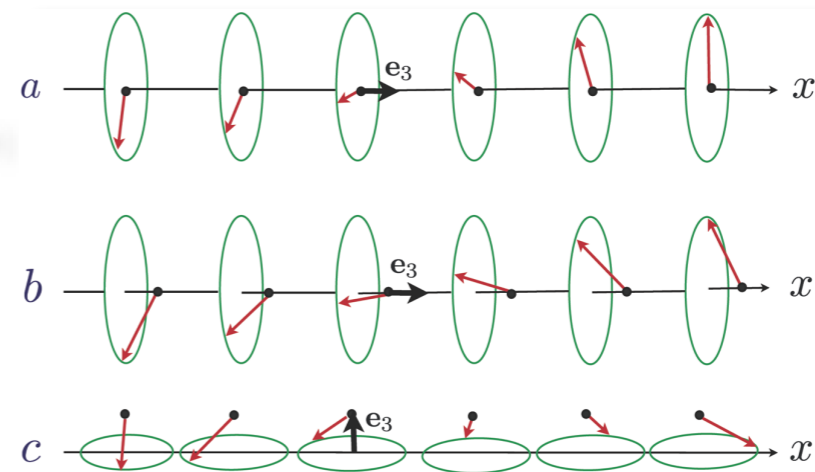
Magnetic order breaks time reversal symmetry. In helical magnets in addition space inversion symmetry is broken with important consequences for the structure of topological defects. Helical magnets are abundant, occurring as **metals and alloys, semiconductors and multiferroics** (most interesting for applications). In **centrosymmetric** systems both symmetries are broken simultaneously, in **non-centrosymmetric** systems space inversion is broken at crystallization. In the most simple case the **order parameter space** consists of two circles, corresponding to a right and a left handed helix, respectively. **Topological defects are vortices and domain walls.** We found that **domain walls include generically a regular pattern of pairs of magnetic vortex lines.** These vortex lines are either closed or terminate on the crystal surface. In multiferroics vortex lines are electrically polarized, but their total charge vanishes. For **special orientations domain walls are vortex free.** These walls are very stiff, showing **non-local elasticity** and are therefore not pinned by impurities.

[1] F. Li, T. Nattermann, V.L. Pokrovsky, *Vortex domain walls in helical magnets*, Phys. Rev. Lett. **108**, 107203 (2012)

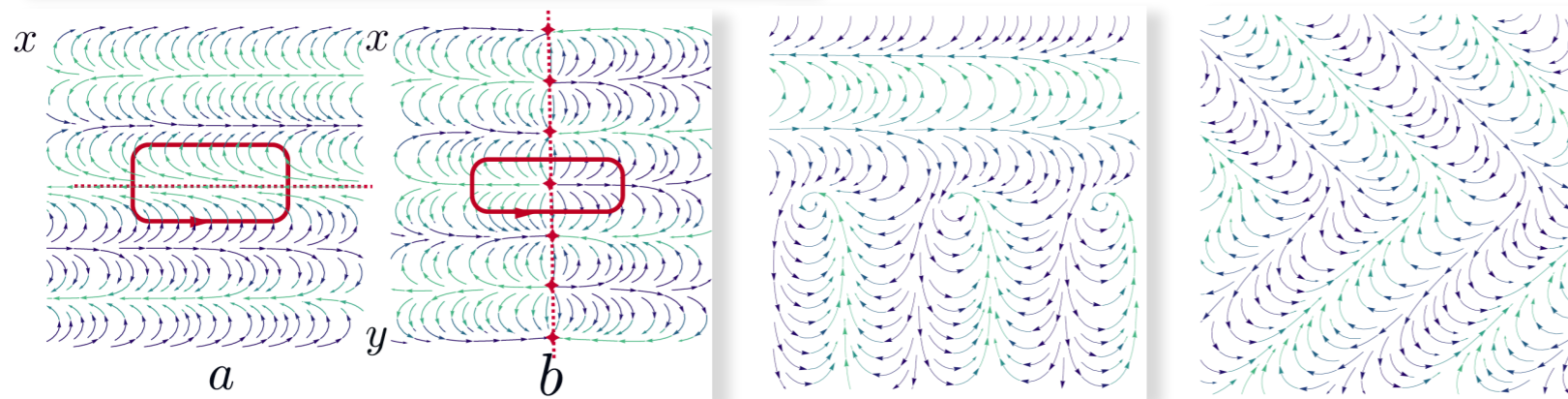
[2] T. Nattermann, *Domain Walls in Helical Magnets: Elasticity and Pinning* [arXiv:1210.1358]



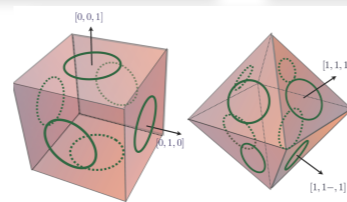
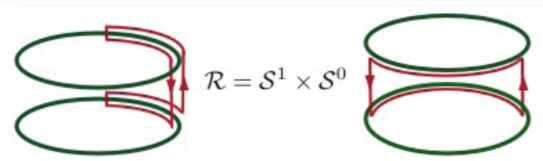
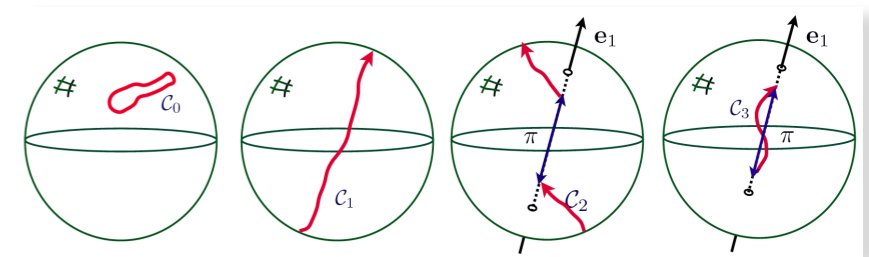
Domain pattern in Ho seen by circularly polarized X-rays of opposite helicity.



Different types of helical ordering. (a) The magnetization rotates in a plane perpendicular to the helical (x) axis as in Tb, Dy, Ho. (b) Conical phase with a nonzero m_3 component of the magnetization as in Ho below 19 K. (c) The magnetization rotates in a plane parallel to the helical axis as in TbMnO₃.



Order parameter space and domain walls



A special situation exist in **two dimensional classical or one-dimensional quantum spin systems**: even if according to Landau theory space and time inversion symmetry breaking should occur simultaneously, **fluctuation effects may lead to a split into two nearby transition** (see phase diagram)

[3] H. Schenck, V.L. Pokrovsky and T. Nattermann *Vector chiral phases in frustrated 2D XY model and quantum spin chains* [arXiv:1308.0823][

