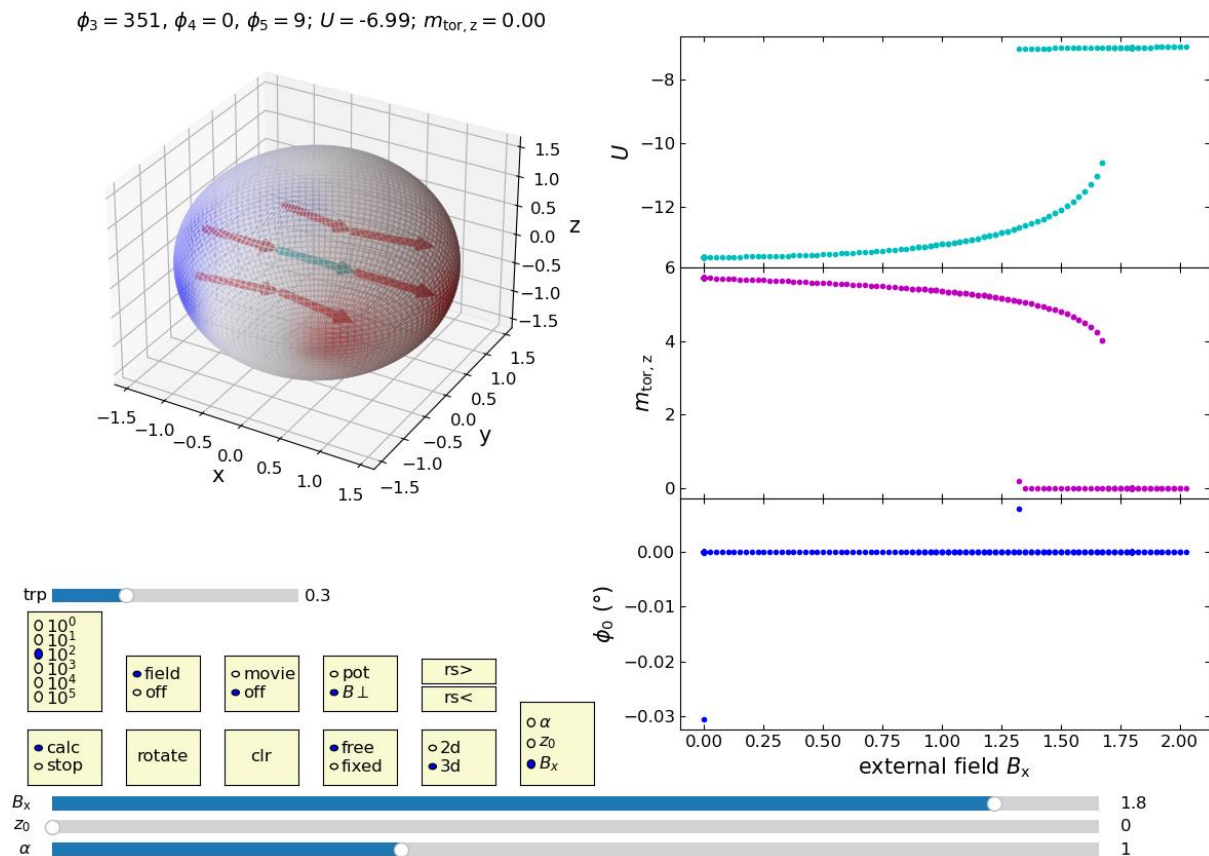


The animation of hysteretic transitions of a **hexagonal magnetic dipole cluster**. Details of the physics are described in <https://doi.org/10.48550/arXiv.2203.13670> and the references cited therein.

The Python code for “animate_dipole_cluster.py”, **Version 1.2.1**, is available here: [10.5281/zenodo.6380539](https://doi.org/10.5281/zenodo.6380539), or from the author Ingo.Rehberg@uni-bayreuth.de

Version 1.2 adds the possibility to raise the central dipole out of the plane of the hexagon (it is thus a 3d-code, might be slower than the 2d-code of version 1.1, also available here).

In Version 1.2.1, an external B-field along the x-direction B_x is introduced as a 3rd control parameter. (a corresponding experiment would require additional coils). In addition, automatic animation scenes can be started and stored as an animated gif.



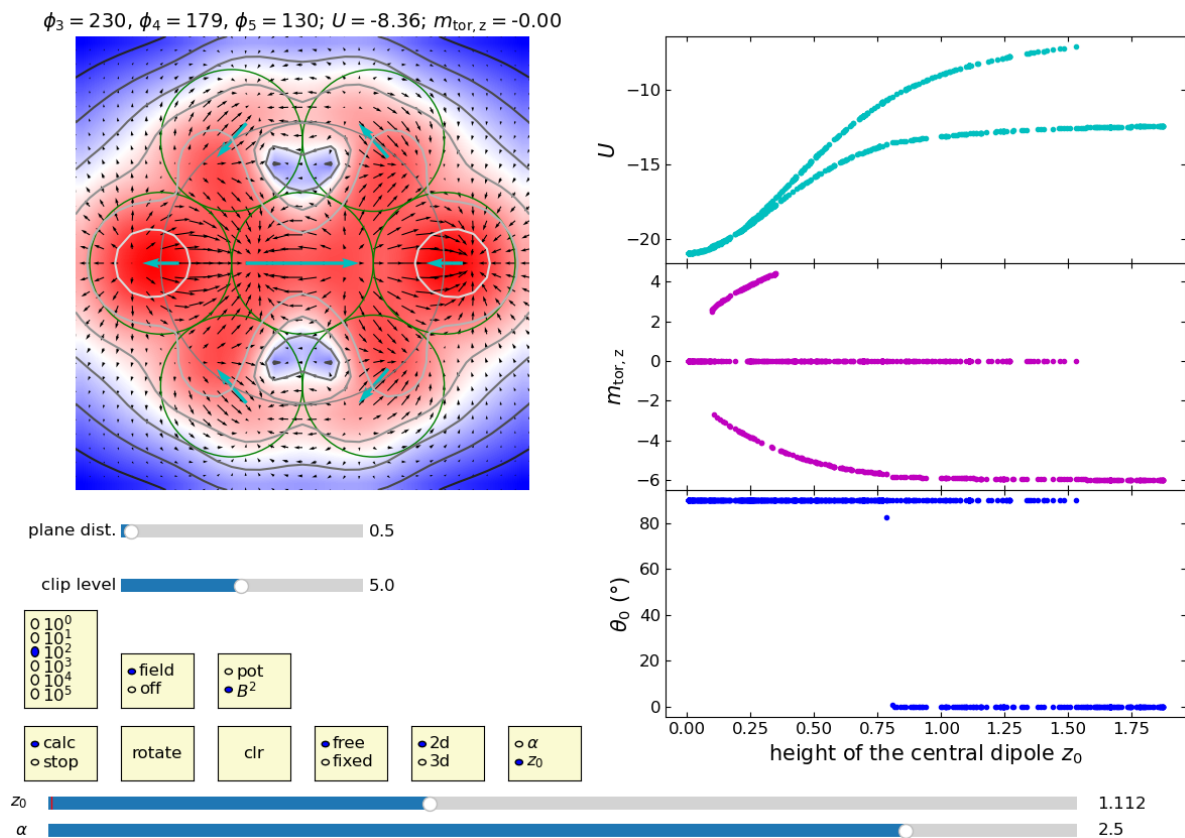
The **3d-figure on the left hand side** shows the seven dipoles in the filled hexagon configuration. Its orientation can be manipulated with the mouse. The title shows 3 of the dipole angles (the other ones can be determined from those due to the symmetry of the circular ground state), the magnetic potential energy U , and the toroidal moment m_{tor} of the present state.

The figures on the right hand side show

- i) the potential energy of the dipole-dipole interaction,
 - ii) the z-component of the toroidal magnetic moment,
 - iii) and the angle of the centre dipole with the x-axis, when that dipole is allowed to rotate freely. When its fixed (set by the fixed/free radio button) the y-component of the toroidal magnetic moment is shown instead.
- **alpha-slider**: Manipulates the strength of the central dipole, the bifurcation parameter.
 - **z0-slider**: Manipulates the height of the central dipole, an alternative bifurcation parameter.

- **B_x -slider:** Manipulates the strength of an external homogenous field along the x-direction.
- **calc/stop radio button:** stop and restart the calculation.
- **rotate button:** Turns all dipoles in such a way that the angle ϕ_0 of the central dipole is within $\pm 30^\circ$ (This is always possible because of the 6-fold symmetry of this problem).
- **clr button:** erases the memory of the stored values for the 3 subplots on the right hand side.
- **fixed/free radio button:** switch between a fixed orientation and a freely rotating mode of the central dipole moment.
- **2d/3d radio button:** Switches between 3d and a 2d (explained below) display of the configuration.
- **$10^0 \dots 10^5$ radio button:** the number of iteration between an update of the figure (beyond 1000 might take very long!).
- **field/off radio button:** Show additional fields or turn them off.
- **Movie/off radio button:** displays the hysteresis without manual interaction.
- **pot/ B_\perp radio button:** The field can be the potential, or the component of the B field perpendicular to the surrounding sphere.
- **rs< button:** decreases the resolution of the “sphere”.
- **rs> button:** increases the resolution of the “sphere”.
- **trp-slider:** sets the transparency level of the sphere.

For the 2d-representation with an active background two additional sliders are available:



- **pot/ B^2 radio button:** Switches between
 - the potential
 - and the field energy density

which is shown on a plane above the planar hexagonal configuration. The vector field indicates the B_x , B_y field components.

- **plane dist. - slider**: determines the distance of the plane from the planar hexagonal configuration.
- **clip level - slider**: Can be used to manipulate the colour distribution of the background. The number denotes a multiple of the standard deviation of the scalar field.