Galaxy Collisions

Magnetic field amplification and starbursts induced by mergers of disk galaxies

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In Short

- Throughout cosmic history, galaxies frequently collide and merge with other galaxies.
- Observations of merging galaxies indicate an enhancement of the galactic magnetic field and, possibly, starbursts.
- We investigate the impact of tidal forces acting during mergers on the magnetic field and star formation rate in adaptive mesh refinement simulations.

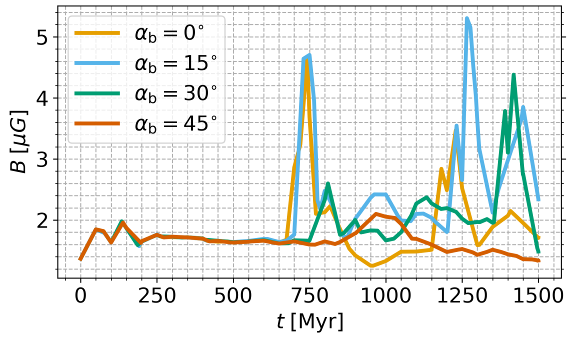

***Figure 1:** Mean magnetic field strength in outer disk regions as function of time in four different simulations. The pronounced peaks indicate magnetic field amplification when the two galaxies are interacting. The angle α_b specifies how close the second galaxy flies by ($\alpha_b = 0°$ corresponds to the central collision visualized in Fig. 2).*

Galaxies are found in groups and clusters, where they cross and distort each other, sometimes colliding and even merging under their mutual gravitational attraction. Interactions between galaxies thus play a significant role in the course of their evolution. For example, there are indications that the magnetic field strength in disk galaxies similar to the Milky Way Galaxy increases during a merger. This is probably caused by the turbulent dynamo effect, i.e. the random twisting and tangling of magnetic field lines. Turbulence in the interstellar medium (the gas inside galaxies from which stars are formed) is mainly driven by supernova explosions as long as a galaxy is isolated. During a merger, strong tidal forces are expected to produce additional turbulence which in turn amplifies the magnetic field.

In our project, we study these effects in numerical simulations of colliding disk galaxies. Our model assumes two initial gas disks in approximate hydrostatic equilibrium surrounded by dark matter halos. While the halo is usually treated by a static gravitational potential in simulations of isolated disk galaxies, we use full N-body dynamics. This method allows us to move the composite system of gas disk and halo relative to the grid and to accurately compute gravitational interactions between the halos, which is an essential prerequisite for galaxy collisions.

We use the publicly available code Enzo, version 2.6 [1], to study a wide range of different scenarios, ranging from central collisions to near misses, where galaxies interact and form tidal tails (similar to the famous Whirlpool galaxy M51) but remain separate objects. Adaptive mesh refinement (i.e. the numerical resolution varies in space and is adjusted in the course of a simulation) allows us to reach a spatial resolution of the order of ten parsec (the radius of a disk galaxy is about 1000 times larger). Since substructure of the interstellar medium extends down to much smaller length scales, we employ an approach known as large eddy simulation (LES) to model small-scale turbulence and its influence on the magnetic field [2,3].

Figure 2 shows an example for a head-on collision of two galaxies of equal mass. The top plots show the two disks just before the collision. At this point the magnetic field is ordered and has spiral-like structure. When the two disks collide, a collision zone can be seen in which the magnetic field is substantially stronger than the initial galactic field (middle plots). The galaxies do not fully merge yet, but move apart until their gravitational attraction pulls them back. The magnetic field is disrupted and becomes highly turbulent after the first interaction (bottom right plot). By averaging the magnetic field in different parts of the disk, we found signatures of strong field amplification (see Fig. 1).

In the next phase of the project, we want to understand what changes come about if the disks do not collide head-on, but are inclined under various angles. Moreover, we aim at a more complete model of disk galaxies by incorporating cooling processes in the interstellar medium, star formation, and feedback by supernova explosions. Since tidal effects trigger turbulence and fragmentation, we expect enhanced star formation activity in the merger phase. The simulation suite we are going to produce will enable us to quantify these effects for various types of mergers.

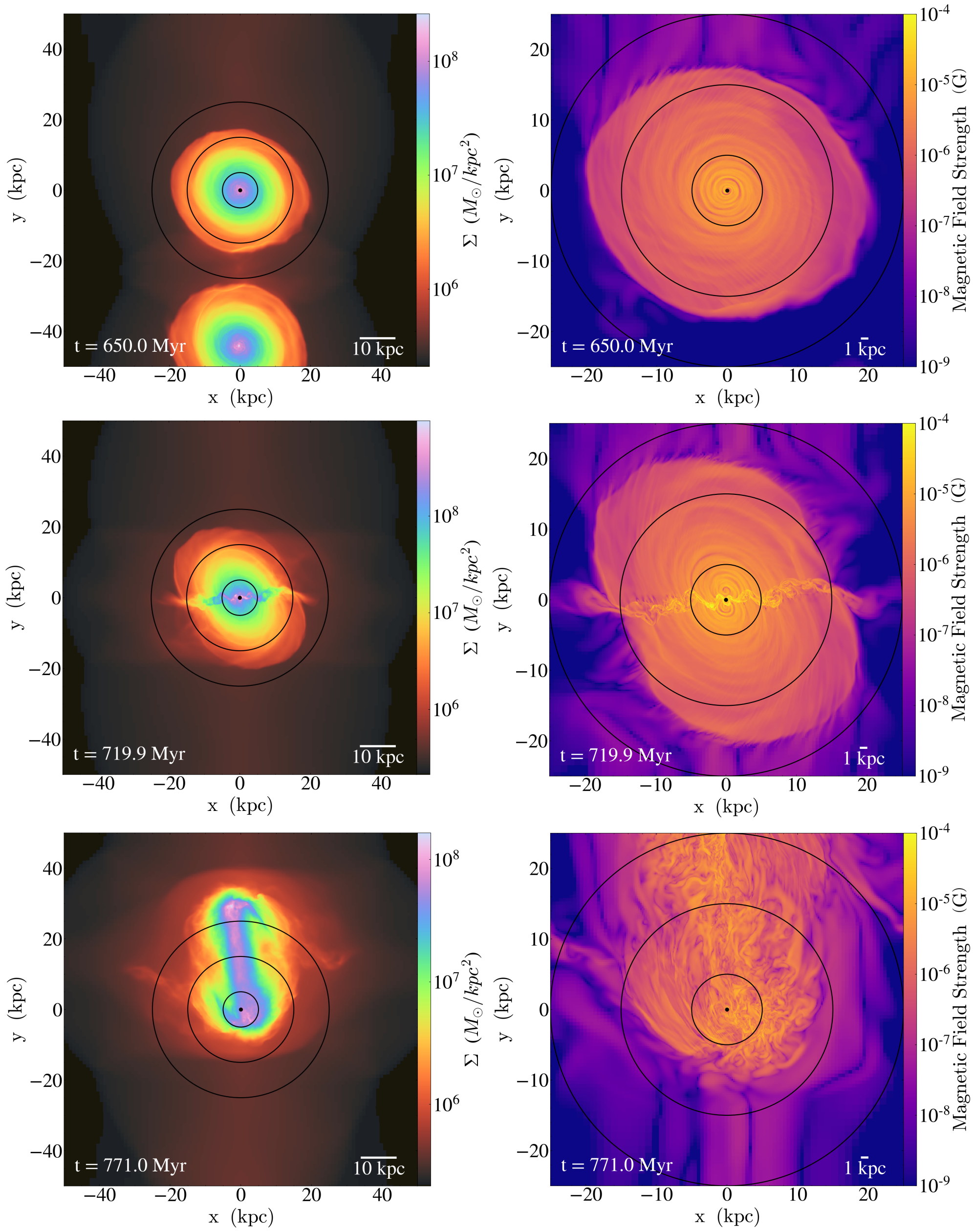

Figure 2: Simulation of a head-on collision of two disk galaxies. The left column shows snapshots of the face-on view of the surface density centered on the primary galaxy before, during, and immediately after the first encounter (from top to bottom). In the right column, the corresponding slices of the magnetic field strength zoomed in by a factor of two are shown. The circles are used to identify different disk regions in which the mean field strength is computed.

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https://www.physik.uni-hamburg.de/en/hs/group-schmidt/research/galaxy-simulations.html

More Information

[1] http://enzo-project.org

[2] W. Schmidt, *Living Reviews in Computational Astrophysics* **1**, 2 (2015). doi:10.1007/lrca-2015-2

[3] P. Grete, D. G. Vlaykov, W. Schmidt, D. R. G. Schleicher, *Physics of Plasmas* **23**, 062317 (2016). doi:10.1063/1.4954304

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