Universität Konstanz

Simulation of magnetic fields in galaxy minor mergers

Ringberg Meeting

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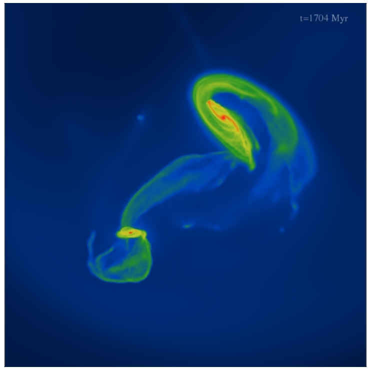
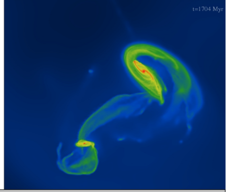


- *Motivation*
- *Initial conditions: galaxy models & orbit*
- *Morphological evolution of density and magnetic field*
- *Magnetic field evolution: dependence on mass ratios, initial magnetic fields and disc orientation*

Motivation

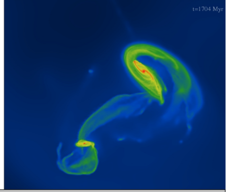


- Observations: magnetic fields of isolated galaxies in the range 1-10 μG, in interacting galaxies 30 μG
- Simulations: amplification of the galactic magnetic field in major mergers up to a saturation value of ~ μG (Kotarba 2010, 2011)
- Galaxy minor mergers → more common events in the Universe

How does the magnetic field evolution in galaxies depend on mass ratios of progenitors?

- GADGET: N-body/SPH code (Tree code, SPH, SPMHD)

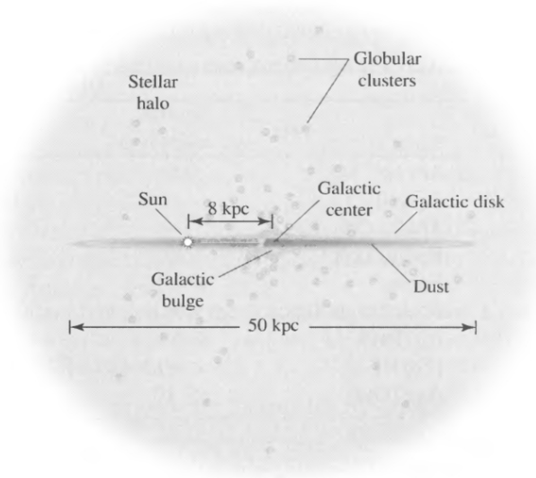
Initial conditions



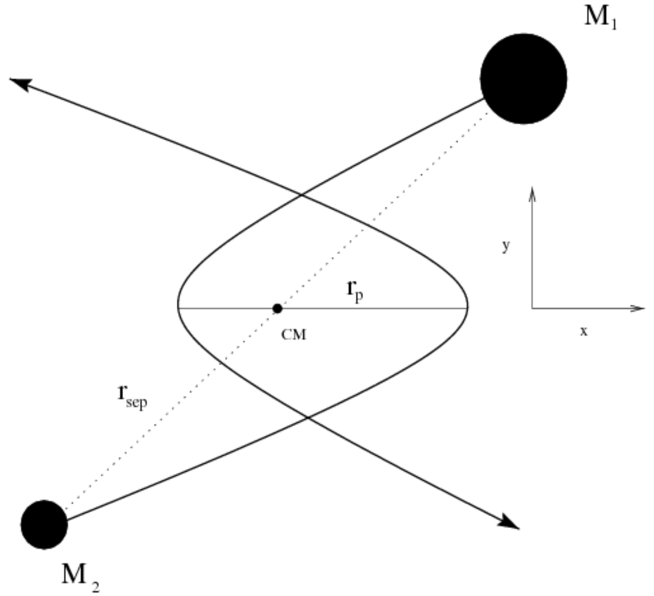
Galaxy models & orbit

Galaxy consists of:

- Exponential gas disk (SPH particles)
- Exponential stellar disc (collisionless)
- Stellar bulge (collisionless)
- Dark matter halo (collisionless)

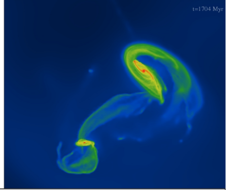


Carroll, B.W. and Ostlie, D.A.,
Introduction to Modern Astrophysics, 2006



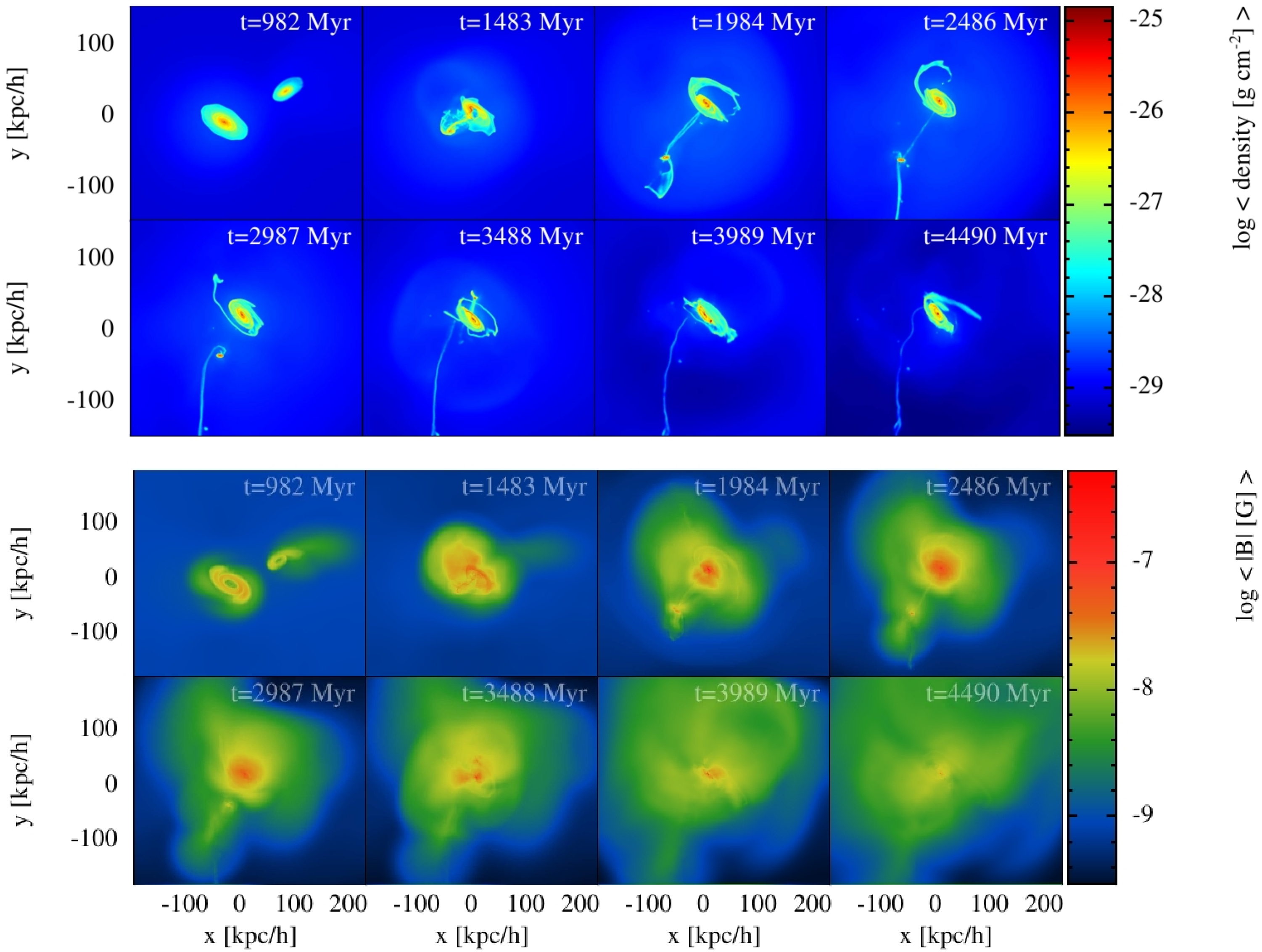
Naab, T., 2000, PhD thesis, University of Heidelberg

- Parabolic, prograde orbit of largest galaxy M1 with different smaller galaxies
- R_{sep} = sum of virial radii, R_p = 7 kpc
- Ambient IGM: particles on hcp lattice

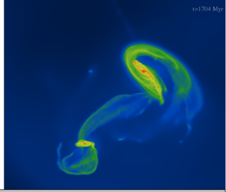


Results: Magnetic field evolution

Morphological evolution of density and magnetic field: M1M4_G6I9

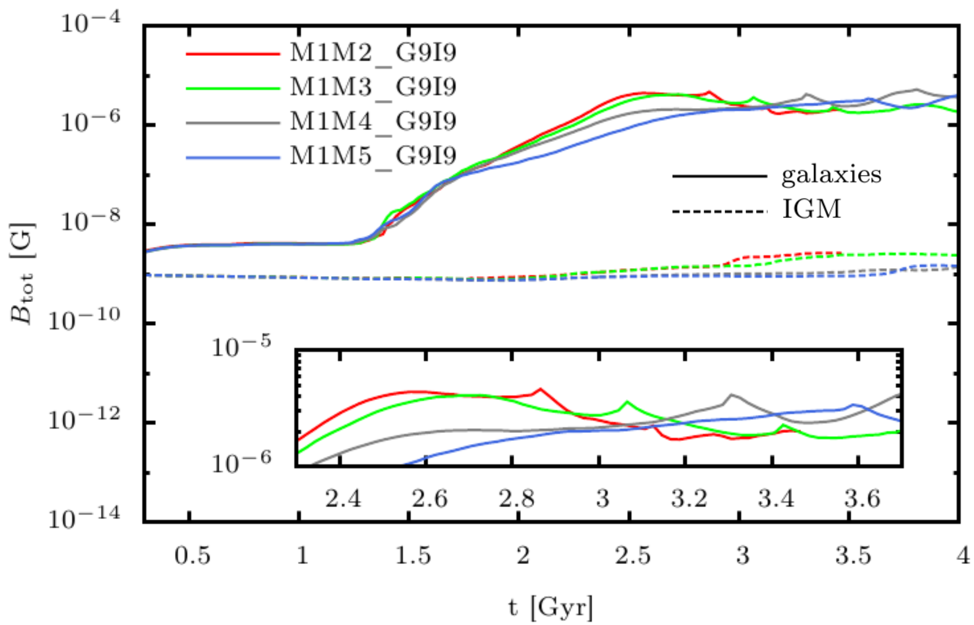


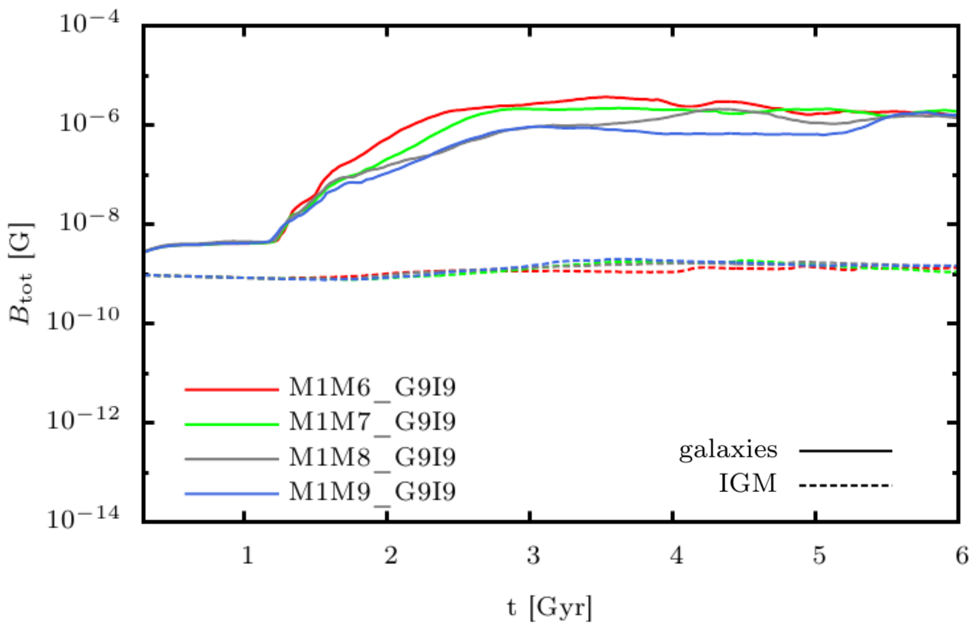
Results: Magnetic field evolution

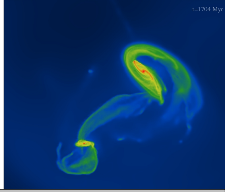


Dependence on mass ratio: scenarios with $B_{\mathrm{gal},0} = B_{\mathrm{IGM},0} = 10^{-9}\ \mathrm{G}$

- Slight amplification due to winding process
- Amplification: maximum value and slope dependent of mass ratios
- Magnetic field strengths saturate at similar values of several µG
- IGM magnetic field gets amplified to saturation value of several nG



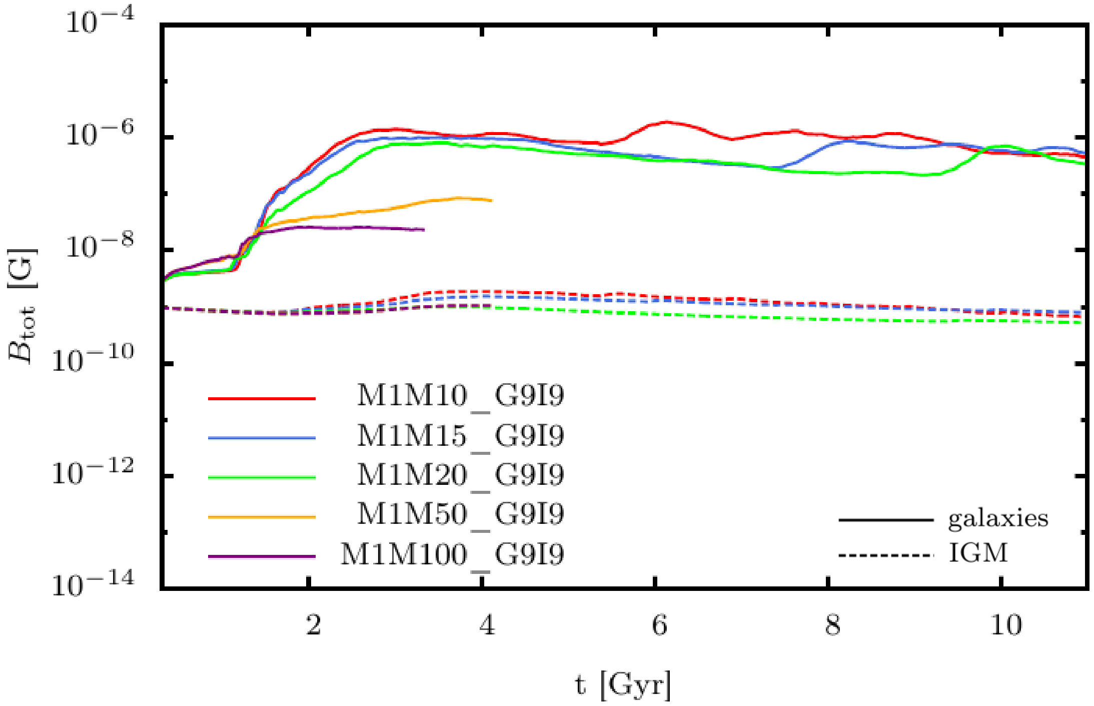




Results: Magnetic field evolution

Dependence on mass ratio: scenarios with $B_{\mathrm{gal},0} = B_{\mathrm{IGM},0} = 10^{-9}\ \mathrm{G}$

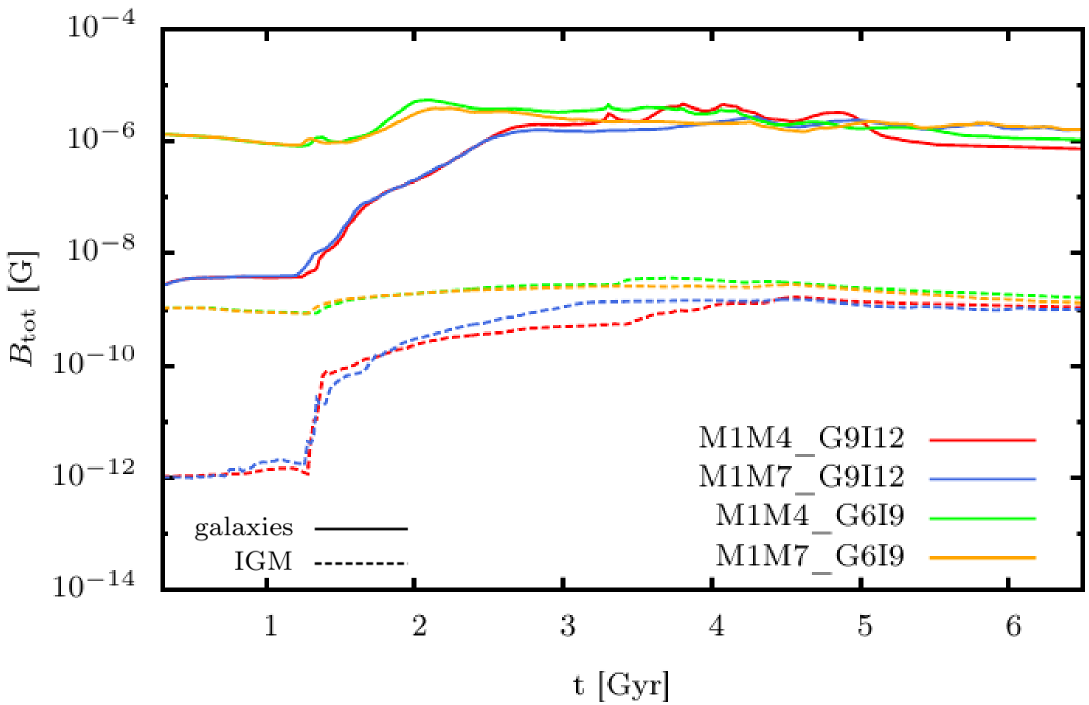
- First encounter leads to magnetic field amplification lower than 1 μG.
- Maximum value reached at the time of 2nd encounter.
- Smaller saturation values of magnetic field



Results: Magnetic field evolution

Dependence on initial magnetic field: scenarios with $B_{\mathrm{gal},0} = 10^{-6}$ G

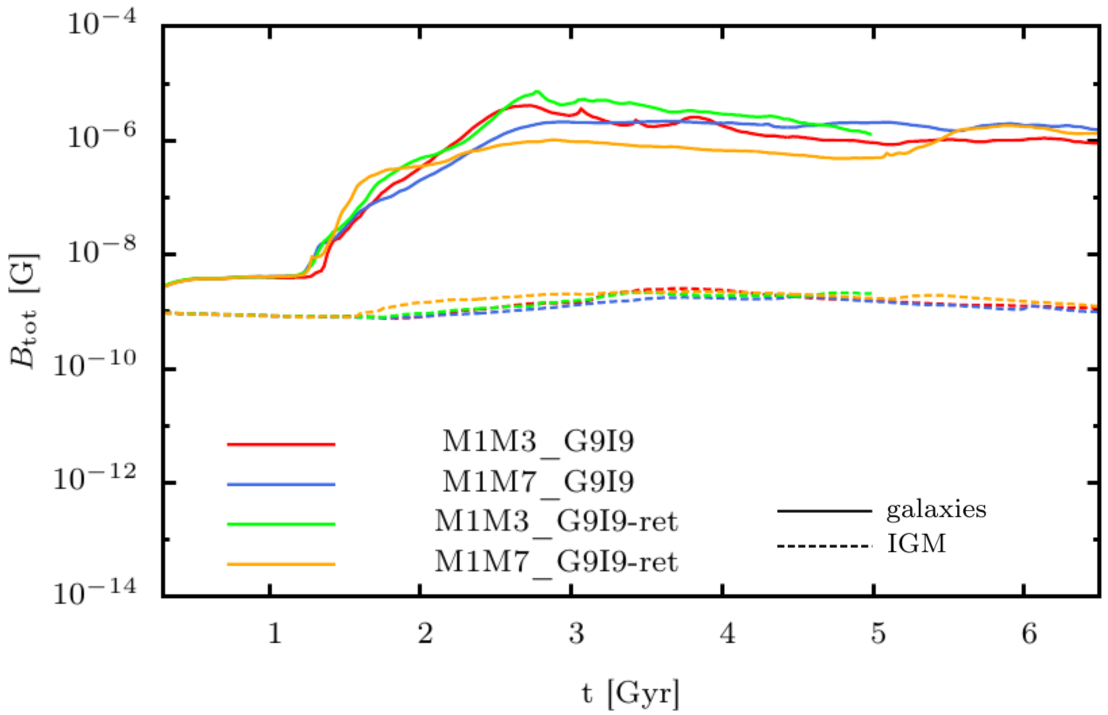
- $B_{\mathrm{gal},0} = 10^{-6}$ G almost corresponds to saturation value
- Small peak at first encounter, followed by a slight amplification
- Saturation value equal to simulations with lower initial galactic field



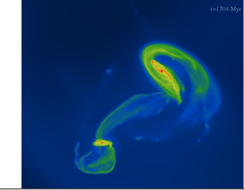
Results: Magnetic field evolution

Dependence on disc orientation: pro- and retrograde scenarios

- Merger scenarios with different disc orientations:
  - Magnetic field amplification slightly more efficient
  - Saturation value approximately equal to saturation of prograde orientation

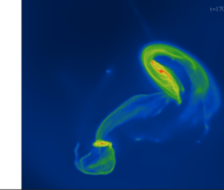


Conclusion



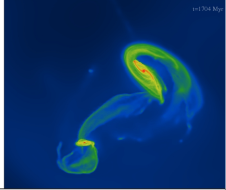
Series of minor mergers including magnetic fields

- **Magnetic field evolution:**
  - slope and maximum value of magnetic field strength dependent on mass ratios
  - similar saturation values for mass ratios of 2:1 up to approximately 10:1, lower saturation values for larger mass ratios
  - disc orientation and initial galactic magnetic field influence the evolution of the galactic magnetic field, but show only marginal effects on the saturation values



Thank you

for your attention!



Self-regulation of amplification

Evolution of pressure components

- Kinetic energy release → turbulence → amplification of magnetic energy
  - ➡ Higher impact energy → more efficient amplification
- Amplification is suppressed by Lorentz-Force
  - ➡ Excessive magnetic energy is converted into gas kinetic energy
- System tends to maintain the equipartition between turbulent and magnetic energy