Minor Mergers

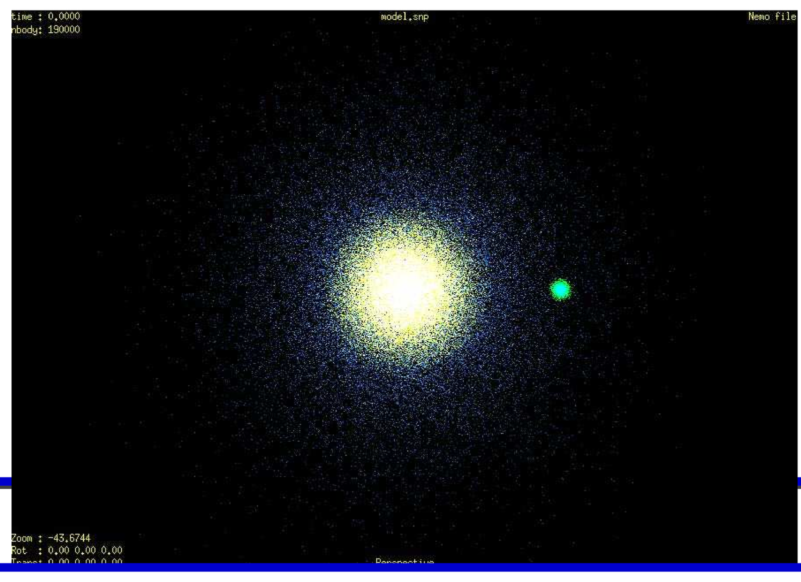
Saulder C.
Institute of Astronomy, University of Vienna, Austria

Abstract

I investigated the behaviour of minor mergers between a disc galaxy and a dwarf spheroidal galaxy using the NEMO-package from Teuben. To simulate the disc galaxy I chosed a KD95-model and for the dwarf galaxy I selected a simple King-model. The spheroidal was placed 40kpc apart from the host galaxy and in the same plane where the disc of this galaxy was located. Several different initial orbits and mass fractions for the galaxies were selected to analyse the behaviour of the minor merging process. The mass fraction was varied between 1/10 and 1/200. The initial speed of the dwarf spheroidal was the circular speed on its starting position. The orbits were either polar with an angle of 30° or 60° respect to the disc or central collisions. I study the merging times and the thickening of the disc due to the merging process. The merging times increase with lesser masses and greater inclination of the orbit. Furthermore the heating effect on the disc is greater with greater masses of the satellite as expected.

Initial Model

A KD95 model has been selected for the spiral galaxy. It consists out of 80000 particles for the disc with a total mass of $3.36910^{10}M_{\odot}$ and 40000 particles having a total mass of $1.64610^{10}M_{\odot}$ for the bulge. Furthermore the galaxy posses a halo with 60000 particles which make up a total mass of $1.90310^{11}M_{\odot}$.
A King-model was chosen for the dwarf galaxy. It contains 10000 particles distributed in a sphere with a diameter of 6kpc. The mass of this galaxy was varied between $2.40310^{10}M_{\odot}(\frac{1}{10} of spiral mass)$ and $1.20210^{9}M_{\odot}(\frac{1}{200} of spiral mass)$. There is no distinction between baryonic and dark matter for the dwarf galaxy.
The dwarf galaxy was placed 40kpc aside the center of the spiral galaxy in the same plane as the disc. The satellites initial speed was the circular velocity for its initial position. I tried three different orbits for the dwarf galaxy. The first one was a direct collision, but the others two were polar orbits. The inclination of the initial velocity vector with respect to the disc' plane were 30° and 60°.



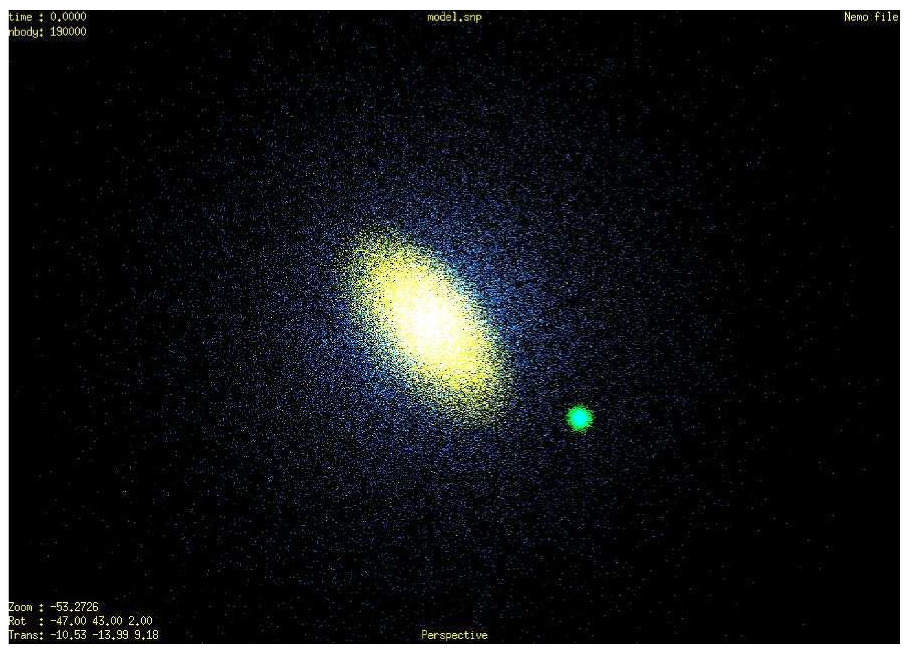
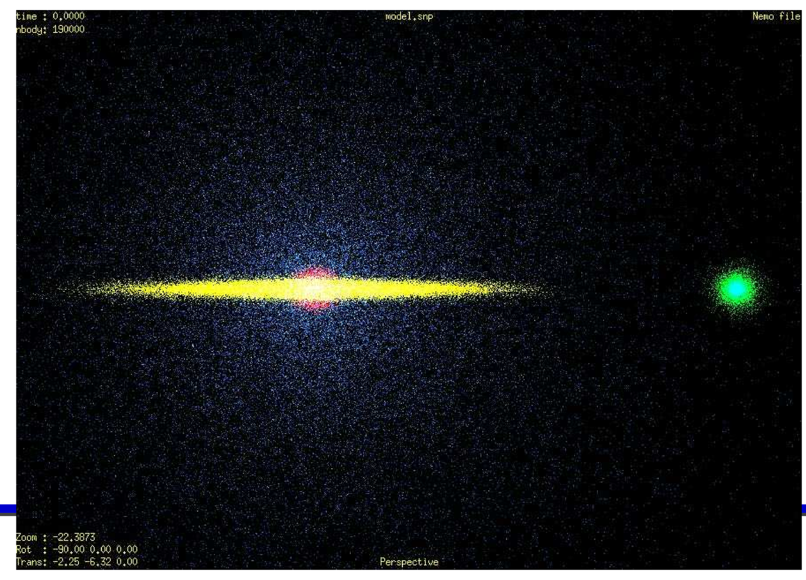


FIGURE 2: 3dimensional picture of the initial model, the disc is displayed with yellow particles, the bulge with red particles, the halo with blue particles and the dwarf galaxy with green particles



Results

I ran 15 simulations with different intial conditions integrating for at least 2 Gigayears up to 8 Gigayears using the gyrfalcON integrator from NEMO. The merging times were measured visually. It is obvious that direct collisions merge significally fast, within 1 Gigayear the process has been completed. The merging takes longer for none-direct collisions and the time increases with increasing inclination of the orbit. Furthermore there is also a strong dependence on the mass of satellite. The merging process is less effective with a lower mass for the dwarf galaxy. It takes for a mass ratio of 1:200 and an inclined orbit of 60° even longer than 8 Gigayears (see Fig. 4).

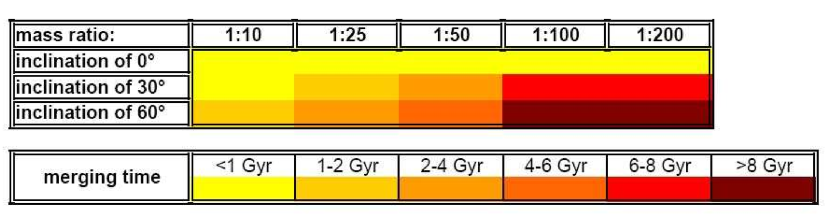


FIGURE 4: the dependence of merging time on the initial parameter of the model

An other aspect of my analysis was the heating of disc of the host galaxy. This process is also depending on both parameters of my survey. As expected the heating effect is smaller for a direct collision than for an inclined orbit, because there is no additional angular momentum and no force orthogonal to the disc' plane. On the other hand, if we have an already inclined orbit, there is no significant depends on its actual inclination. Mergers with a more massive dwarf are of course more violent than those with less massive ones, so we expect the heating effect to be stronger for a higher mass of the satellite. My simulations are conforming this expection very well. To measure the heating effect on the disc I used the z-velocity component of the disc' particles and calculated its dispersion after the merging event. (see Fig.5)

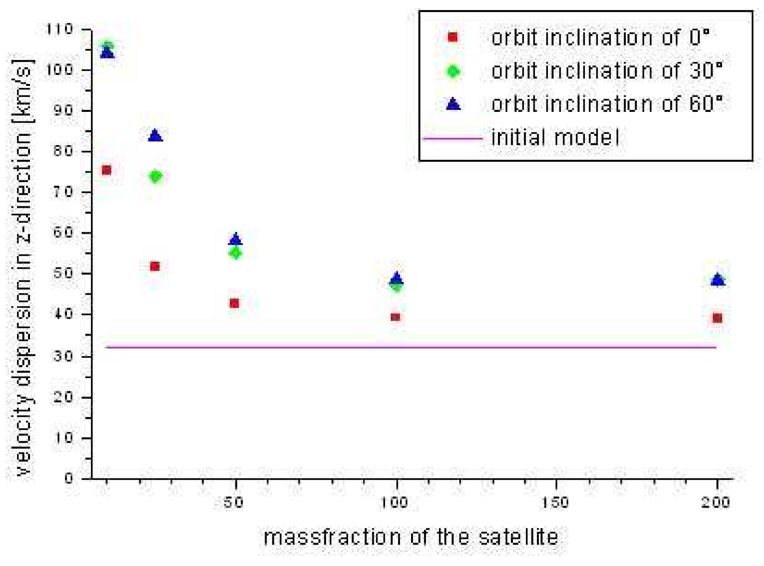


FIGURE 5: the dependence of disc' z-velocity dispersion on the initial parameter of the model

The main structure of the host galaxy was hardly affected for low mass satellites, but for high mass satellites(like $\frac{1}{10}$of the spiral's mass), which was almost a mayor merger, it resulted in different type of disc galaxy. Furthermore the effects of forming spiral arms and other substructures got significantly stronger with higher masses for the dwarf galaxy(see Fig.6). If we only obsever the the distribution of the dwarf galaxy during the merging process, we will see long tidal tails, which traces a large part of the infalling galaxy's orbit(see Fig. 8). It toke, of course depending on the dwarf's mass between two and six passages for none-direct collisions until the galaxies were merged. Each passage remained visible in some remnant particles of the dwarf galaxy. The core of the satellite finally settled in center of its host galaxy and became a part of its bulge (see Fig. 7).

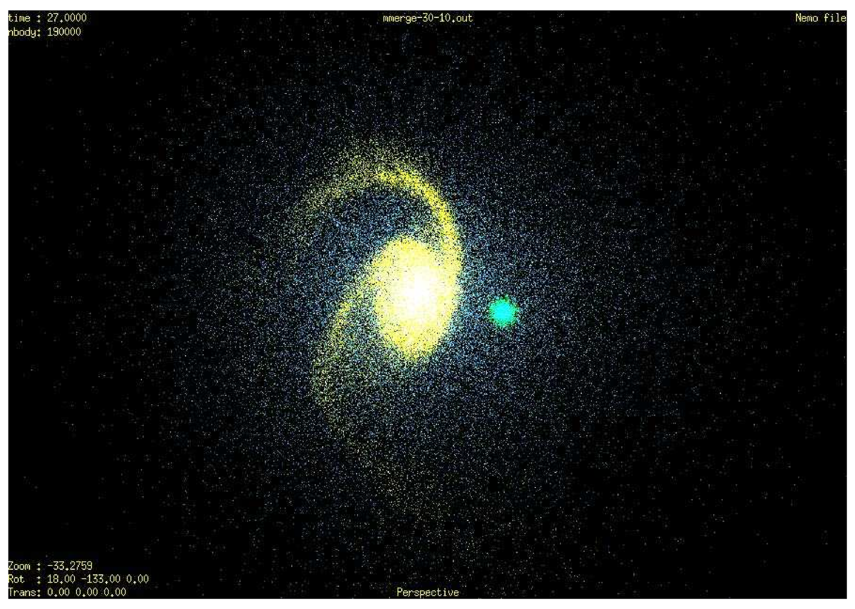


FIGURE 6: a violent merging process: the dwarf galaxy had $\frac{1}{10}$ of host galaxy's mass, the snapshot was taken after 500Myr

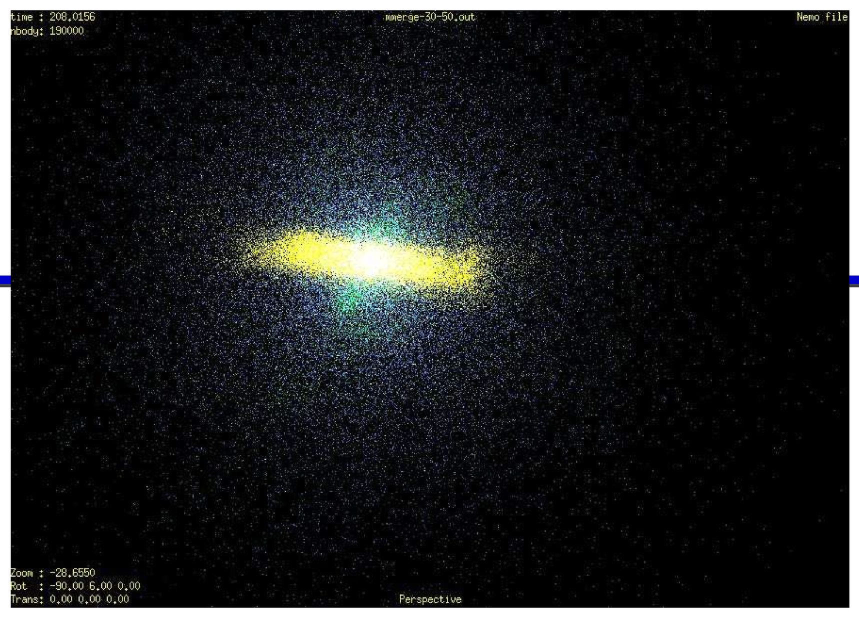


FIGURE 7: the resulting galaxy after merging with a dwarf that had $\frac{1}{50}$ of the spiral's mass; 4Gyr had passed since the beginning

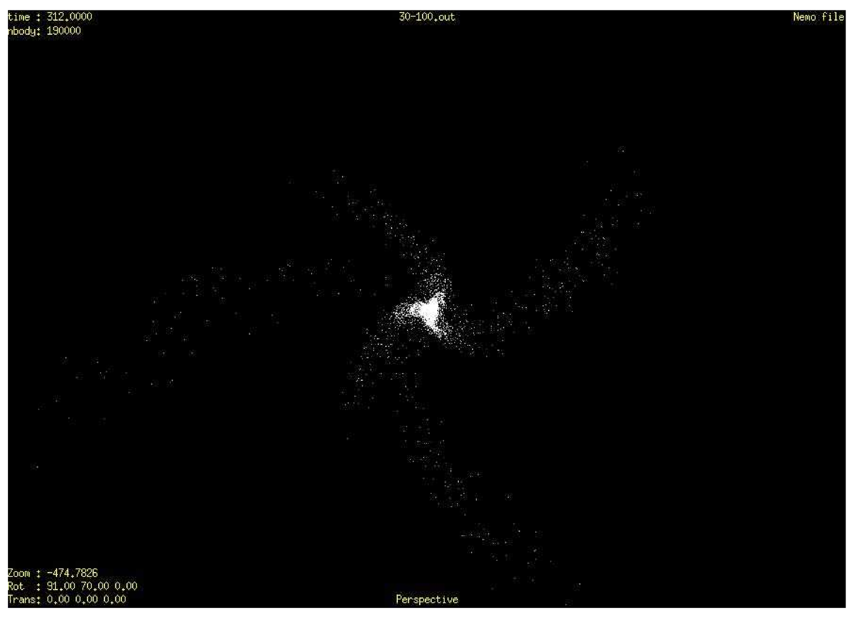


FIGURE 8: the distribution of the dwarf-galaxy's particles after a merging process

Conclusion

The minor merging process of a dwarf spheridoal galaxy with a Milky-way like spiral galaxy shows clear dependences on the parameters of my simulations. The merging time increases with a lower mass of the satellite and with higher inclinations of its orbit. I measured the effect on the galactic disc using the z-velocity distribution of the disc particles. It mainly depends on the mass of the infalling satellite and fewer on its angle. The velocity dispersion after the merger is always greater than its initial value and the effect is stronger for larger masses. Although all minor mergers leave traces like tidals tails, an easy visible effect on its host galaxy will only occure if the satellite's mass is large enough.

References

Quinn, P.J., Hernquist, L. and Fullagar,D.P.; 'Heating of Galactic Disks by Mergers'; ApJ 403 (1993)
Matteo, P.; 'On the frequency, intensity and duration of starburst episodes triggered by galaxy interactions and mergers'; A&A 492 (2008)
Quinn, P.J. and Goodman J.; 'Sinking Setellites of Spiral Systems'; ApJ 309 (1986)
Teuben, P.J.; 'The Stellar Dynamics Toolbox NEMO'; PASP Conf Series 77 (1995)
Kuijken, K. and Dubinski, J.; 'Nearly Self-Consistent Disk-Bulge-Halo Models for Galaxies'; (1995)
King, I.; The structure of star clusters. III. Some simple dynamical models'; AJ71 (1966)