

Heating up galaxies in the cold of space

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Content of this talk

- Initial model
- Simulations
- Merging times
- Heating of the disc
- Remnants of the dwarf galaxy
- Conclusion

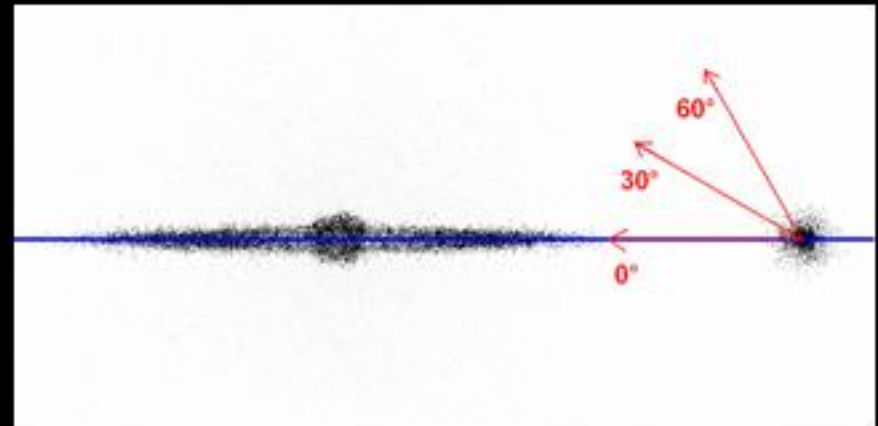
Initial Model

- Stellar dynamics only
- Disc galaxy: Kuijken-Dubinski A-model consisting of 180000 particles (80000 disc, 40000 bulge, 60000 halo) with a total mass of $1.9 \cdot 10^{11}$ solar masses
- Dwarf galaxy: King-Model consisting of 10000 particles

Initial distance: 40 kpc

Initial velocity = circular velocity = 162 km/s

Different directions of relative velocity of the dwarf galaxy: inclination 0° , 30° and 60°



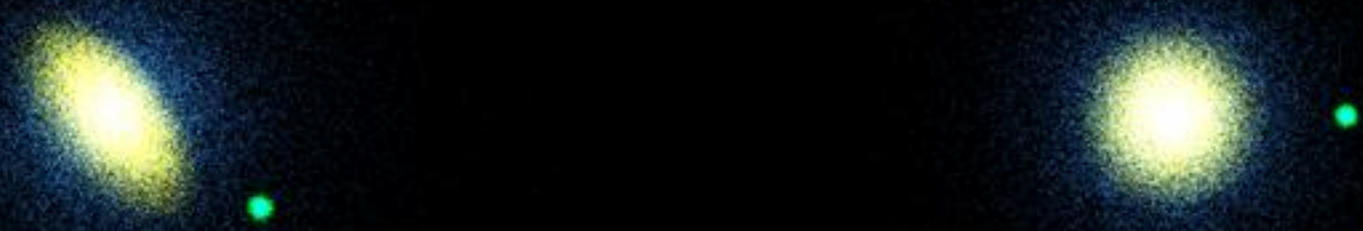
Different mass ratios of dwarf galaxy and disc galaxy:
 $1/10$, $1/25$, $1/50$, $1/100$ and $1/200$

yellow = disc
red = bulge
blue = halo
green = dwarf

Zoom: 0,000
Rot: 180,00 0,00 0,00
Transl: 0,00 0,00 0,00



Zoom: -02,003
Rot: 1 90,00 0,00 0,00
Transl: -0,25 -4,02 0,00



Zoom: 0,000
Rot: 180,00 0,00 0,00

model_001

New file

Zoom: 0,000
Rot: 180,00 0,00 0,00

model_001

New file

Zoom: -02,2706
Rot: 1 -07,00 45,00 2,00
Transl: -03,00 -13,00 0,00

Perspective

Zoom: -02,0744
Rot: 1 0,00 0,00 0,00
Transl: 0,00 0,00 0,00

Perspective

Simulations

- using NEMO-package by P.J. Teuben
- Stellar dynamical N-body simulation
- gyrfalcON tree-code for numerical integration
- ran 15 simulations with different initial conditions
- Integration time 2 Gyr (in case merger was not finished extended up to 8 Gyr)

➤ mass fraction = 1:10; inclination = 30°

File : 9,309
rbody: 13309

merge=0=10,az:

New File : 9,309
rbody: 13309

merge=0=10,az:

New File

Zoom : -41,0021
Rot. : 4,33 0,39 0,08
Trans: 0,33 0,39 0,08

Perspective

Zoom : -41,0021
Rot. : -50,00 3,00 0,00
Trans: 0,33 0,39 0,08

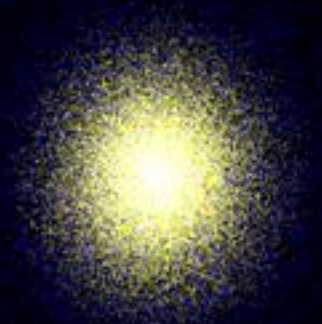
Perspective



➤ mass fraction = 1:50; inclination = 0°

File: 1_300
rbody: 13300

merge-0-50.out



File: 1_300
rbody: 13300

merge-0-50.out



View: -0.2773
Rot: 1 4.33 4.33 0.00
Trans: 4.33 4.33 0.00

Perspective

View: -0.2773
Rot: 1 -90.00 -1.00 4.00
Trans: 4.33 4.33 0.00

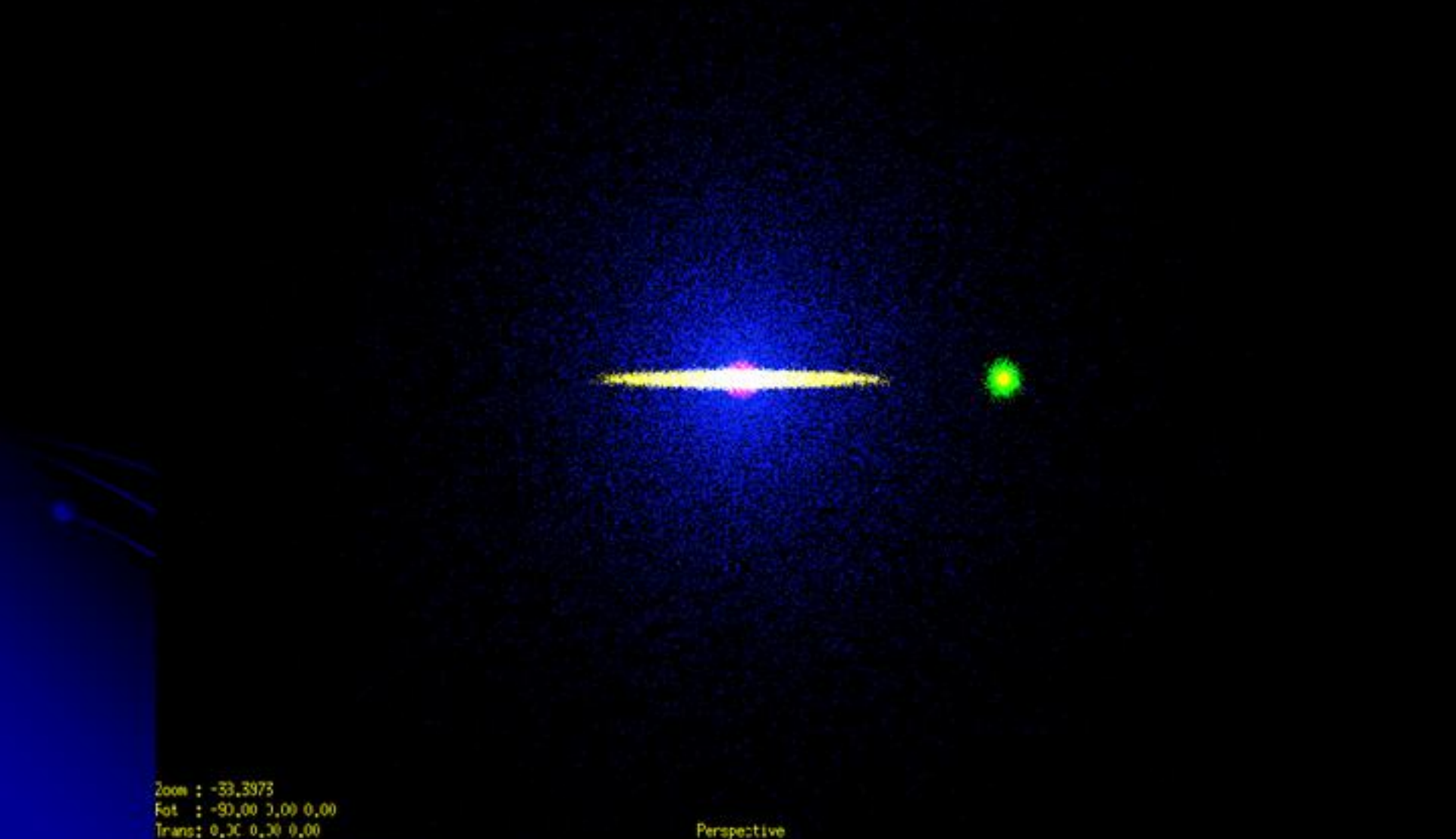
Perspective

➤ mass fraction = 1:200; inclination = 60°

time : 0,3000
rbody: 19000

merge-60-200_cut

View file



Merging Times

- Measured 'visually'
- Increases with inclination of the dwarf's orbit
- Decreases with the mass of dwarf

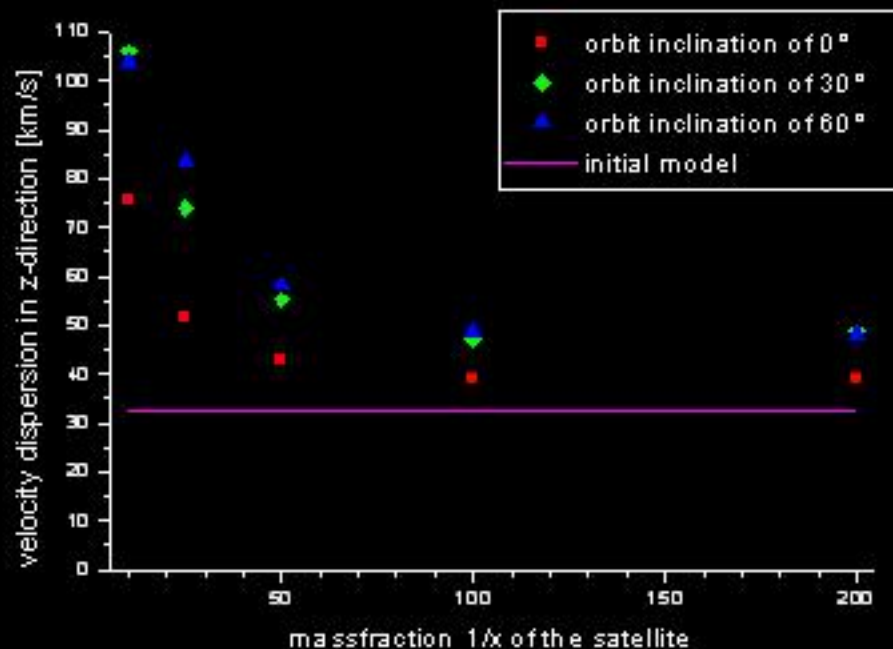
mass ratio:	1:10	1:25	1:50	1:100	1:200
inclination of 0°	Yellow				
inclination of 30°	Yellow	Orange	Red-Orange	Red	Dark Red
inclination of 60°	Yellow	Orange	Red-Orange	Dark Red	Dark Red

merging time	<1 Gyr	1-2 Gyr	2-4 Gyr	4-6 Gyr	6-8 Gyr	>8 Gyr
	Yellow	Orange	Red-Orange	Red	Dark Red	Dark Red

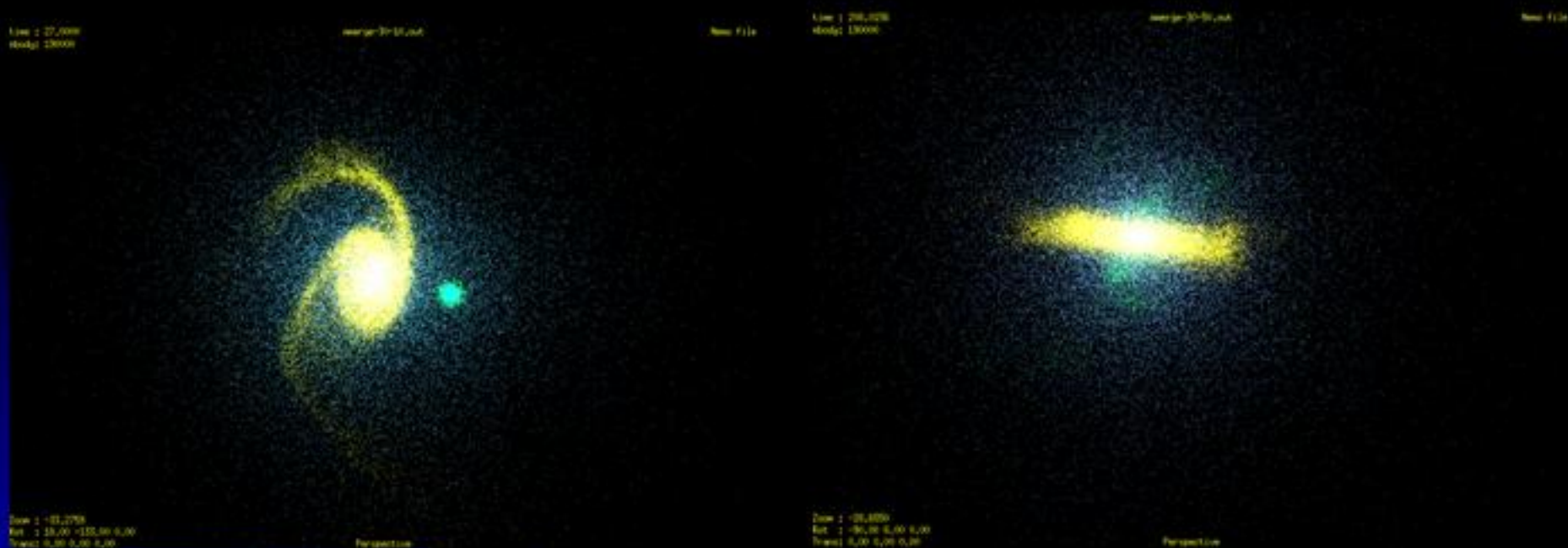
Heating of the disc

- Dwarf galaxy on polar orbit
- force normal to the galactic plane
- distortion of star in disc
- Increases vertical velocity distribution
- Galactic disc gets thicker/hotter

- Heating measured by the z-component of the velocity distribution of the disc particles
- Heating strongly depends on mass of the dwarf
- Little dependence on inclination of inclined orbit
- Only small effect if central collision because no additional force normal to disc



- Visible features of interaction stronger with higher mass of dwarf galaxy
- For high mass dwarfs: significant transition of the disc galaxy's morphology



Remnants of the dwarf galaxy

- The core of the dwarf settles in the bulge
- Tidal arms remain some time after merging process is finished

- Each orbit of the dwarf is visible but contrast will be too small

Time: 1 000,000
Model: 10000

0-100,000

View: Full

Time: 1 -414,000
Axis: 1 00,00 70,00 0,00
Orbit: 0,00 0,00 0,00

Perspective

Conclusions

- Merging time of minor mergers decreases with the mass of the dwarf but increases with the inclination of the dwarf's orbit
- Heating of the galactic disc depends on the dwarf's mass but hardly on its orbit
- The visible effect on the structure of the host galaxy is stronger with a higher mass of satellite galaxy
- Core of dwarfs settles in bulge of disc galaxy