FAULKES TELESCOPE

Galaxies

Interacting Galaxies - Making Ellipticals Teacher Notes

Author: Sarah Roberts

Making Ellipticals

Making Ellipticals - Changing Galaxy Mass

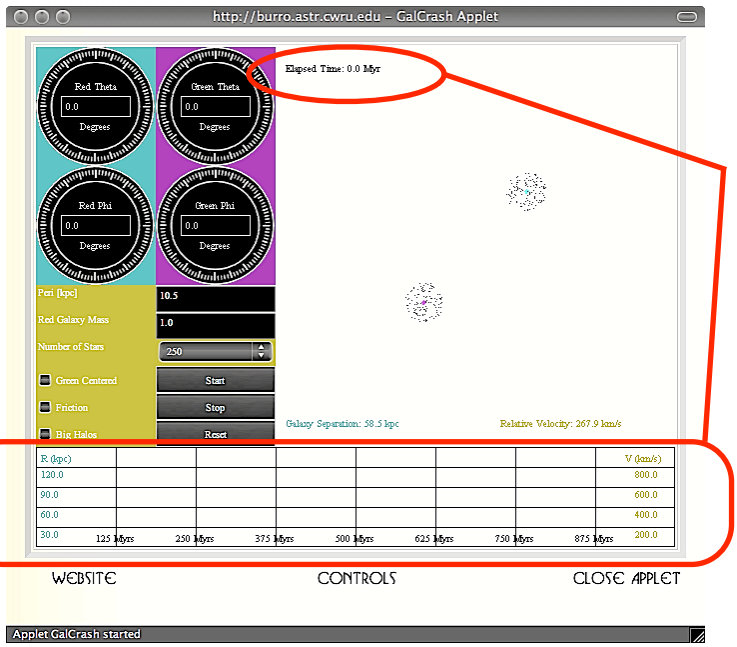
1. Enter the following parameters into the relevant boxes in the Galaxy Crash applet, **leaving the other parameters set as their default values**:

Peri [kpc] = 10.5
Red Galaxy Mass = 1.0
Number of Stars = 1000
Friction* = select box

Click '**Reset**', then '**Start**'.

Watch the graph at the bottom of the window, as well as the animation of the galaxies as time increases and answer the following questions.

a). When do the galaxies come closest together for the first time?



*After approx. 170 Myr. This can be seen by looking at the plot of R (kpc) vs. Time on the graph at the bottom of the applet, and seeing when R is at a minimum. If you press '**Stop**' at this point, you can read the exact time off the top of the window.*

b). What happens to the relative velocities of the galaxies as they reach their point of closest approach?

The relative velocities peak at approximately 540 km/s.

Galaxies

c). As time increases, do the galaxies come together again? If so, after how long?
(**Hint**: when the galaxies merge, the separation on the graph should be around zero)

Yes they do, after about 500 Myrs.

2. Now change the value for the red galaxy mass to 5.0, **leaving all other parameters the same**.
Click '**Reset**' and '**Start**'.

a). When do the galaxies come closest together for the first time? Does this differ from the first simulation?

After approx. 175 Myrs. This is the same as in the previous simulation.

b). What peak relative velocity do the galaxies reach in this case? How does this compare to the previous simulation? Explain why you think these values are different.

The galaxies reach a peak relative velocity of just over 800km/s. In the previous simulation this was 540km/s. For a bigger mass of galaxy, the faster the interaction between the galaxies.

c). How long does it take for the galaxies to merge in this situation? How does this compare to the previous simulation?

The galaxies merge after about 750 Myrs. This is longer than the previous simulation, thus the larger the galaxy mass, the longer it takes for the galaxies to merge.

d). Predict what would happen if you increase the mass of the companion galaxy (e.g. faster/slower merging, higher/lower peak relative velocity etc)

From looking at the previous results, if you increase the mass of the galaxy, the time for merging increases also. However, galaxies travel faster relative to each other, so the initial intreaction is a quicker interaction with higher mass galaxies.

3. Continue to increase the red galaxy mass by 5.0 for each run, and re-run the simulation up to a mass of 15.0. Remember that the elapsed time is also given at the top of the applet window, as well as on the graph, and the simulation can be paused at any time by clicking '**Stop**'.

a). Do your observations from these simulations match your predictions from Question 2 (d)?

HINT: *The best way of determining when galaxies have merged is to watch the red and green dots, which represent the centres of the galaxies, until they overlap and stop the simulation when the galaxy separation in the applet window is approx 0.*

Red Galaxy with Mass 10:

- *Galaxies merge after approx. 1425 Myrs.*
- *Peak relative velocity ~ 950 km/s*

Red Galaxy with Mass 15:

- *Galaxies merge after approx. 2555 Myrs.*
- *Peak relative velocity ~1064 km/s*

So, as mass increases, the time it takes for the galaxies to merge increases also, as predicted. Also, interaction peak velocity increases, so the initial interactions are quicker as the mass increases.

b). How does the formation of the elliptical galaxy change as you increase the companion (red galaxy) mass?

As the galaxy mass increases, the time it takes for the galaxies to merge increases also, so the time it takes for elliptical galaxies to form increases with galaxy mass.

Making Ellipticals - Changing Galaxy Distance

4. Enter the following values into the Galaxy Crash applet, **keeping other parameters set as their default values**:

Peri [kpc] = 15
Red Galaxy Mass = 1.0
Number of Stars = 1000
Friction = selected box

Click '**Reset**', then '**Start**' and watch how the galaxies interact and eventually form an elliptical galaxy.

a). How do you think the formation of an elliptical galaxy would change as you increase the value for **Peri**?

It would take longer to form an elliptical galaxy as peri increases because the force of gravity on the galaxies gets weaker as distance between them increases. Eventually the galaxies won't merge at all.

5. Increase the **Peri** distance from 15kpc to 20 kpc. Make sure you click '**Reset**' before the start of the simulation.

a). How does the formation of an elliptical galaxy change as you increase the distance of closest approach (Peri)? How does this compare to your prediction from Question 4 (a)?

For a Peri distance of 15 kpc, it took approx. 800 Myrs to form an elliptical galaxy. For a Peri distance of 20 kpc, the galaxies don't merge at all. They just fly past each other and disturb each other.

6. Set the Peri distance to 17 kpc. Describe what happens to the 2 galaxies as time increases (**Hint:** Keep watching this simulation until around 6000 Myrs have passed).

The initial interaction is followed by the galaxies moving apart, stopping, and then coming back together. They then move apart again, halt and then come back in towards each other. One big disk of stars forms, but the centres are not aligned. The red and green points which represent the centre of the galaxies, move apart, slow down, fall back towards a common centre of mass, then shoot out again. They don't ever merge properly. If you drag the view so that the galaxies are edge-on, you can see the red and green points travel past each other clearly.

Making Ellipticals – Changing Galaxy Angle

7. Enter the following values into the applet, **keeping all other parameters set as their default values**:

Peri [kpc] = 10
Red Galaxy Mass = 1.0
Number of Stars = 1000
Friction = select box

Change the angle of inclination of the green galaxy (theta) to 90 degrees so that it appears edge-on in the simulation.

Click '**Reset**' and '**Start**' to begin the simulation. The simulation can be viewed from various angles by clicking on the animation window and dragging the screen.

a). Investigate how the inclination angle of the green galaxy affects the formation of an elliptical galaxy by varying theta for the green galaxy from 0 to180 degrees in steps of 45 degrees. Describe below what happens as theta changes.

0 degrees:

- *Peak velocity = 550 km/s*
- *Equal size tidal tails form on both galaxies*
- *Both galaxies rotate anti-clockwise*
- *Elliptical galaxy forms just under 500 Myrs*

45 degrees:

- *Peak velocity = 550 km/s*
- *Green galaxy tails form in plane of 45 degrees compared to red galaxy tails*
- *Green galaxy tails look slightly smaller than red galaxy tails*
- *Both galaxies rotate anti-clockwise*
- *Elliptical galaxy forms just under 500 Myrs*

90 degrees:

- *Peak velocity = 550 km/s*
- *Very short tails form on green galaxy compared to red galaxy*
- *Both galaxies rotate anti-clockwise*
- *Elliptical galaxy forms just under 500 Myrs*
- *Merged galaxy has one tidal tail compared to 2 in previous 2 cases*

135 degrees:

- *Peak velocity = 550 km/s*
- *Green galaxy does not form any tidal tails, but it is disturbed*
- *Green galaxy rotates clockwise, the red galaxy rotates anti-clockwise*
- *Elliptical galaxy forms just under 500 Myrs*

180 degrees:

- *Peak velocity = 550 km/s*
- *Green galaxy does not form any tidal tails, but it is disturbed*
- *Green galaxy rotates clockwise, the red galaxy rotates anti-clockwise*
- *Elliptical galaxy forms just under 500 Myrs*

8. Using your knowledge of how distance of closest approach, galaxy mass and inclination angle affect the formation of elliptical galaxies, try to find the best combination of parameters for producing a typical looking elliptical galaxy in the shortest time. Comment on why that combination is best, and which combination of parameters were worst.

The following is an example answer only - there are many different ways in which elliptical galaxies can be formed using Galaxy Crash. The answer below will just give an idea of the sorts of things to think about when running your simulations.

From Question 7, it seems that the angle of inclination does not affect the time it takes for ellipticals to form, so this parameter can be ignored.

From Questions 4 to 6 we can see that increasing Peri means it takes longer for ellipticals to form, so we want to choose small values for Peri.

From Questions 1 to 3 we can see that increasing the mass of a galaxy means the time for merging and forming ellipticals increases also, therefore we want to choose low mass galaxies.

Therefore, for shortest merging and formation times of ellipticals, you would think from the above that the best parameters are :

any inclination angle
small Peri value
low mass value for red galaxy

Conversely, the worst parameters would be:

any inclination angle
high Peri value
high mass value for red galaxy

***However**, when you combine all 3 parameters, they may not work as well as they did individually. The combination must be investigated e.g.*

For:

Theta = 0 degrees, Peri = 0.1 kpc, Mass = 0.1 - the elliptical galaxy takes approx. 1200 Myrs to form.

For:

Theta = 0 degrees, Peri = 0.1 kpc, Mass = 1.0 - the elliptical galaxy takes approx. 412 Myrs to form.

Play with the values until you reach the lowest time that you can.