Galaxy Collisions

Haukur Sigurdarson

Chalmers University of Technology

haukurs@student.chalmer.se

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Overview

- How do galaxies collide?
- Are galaxy collisions rare?
- What effects do collisions have on structure and star formation?
- What kind of collisions are there?
- What do collisions look like?
- What is the end result?

Pretty pictures

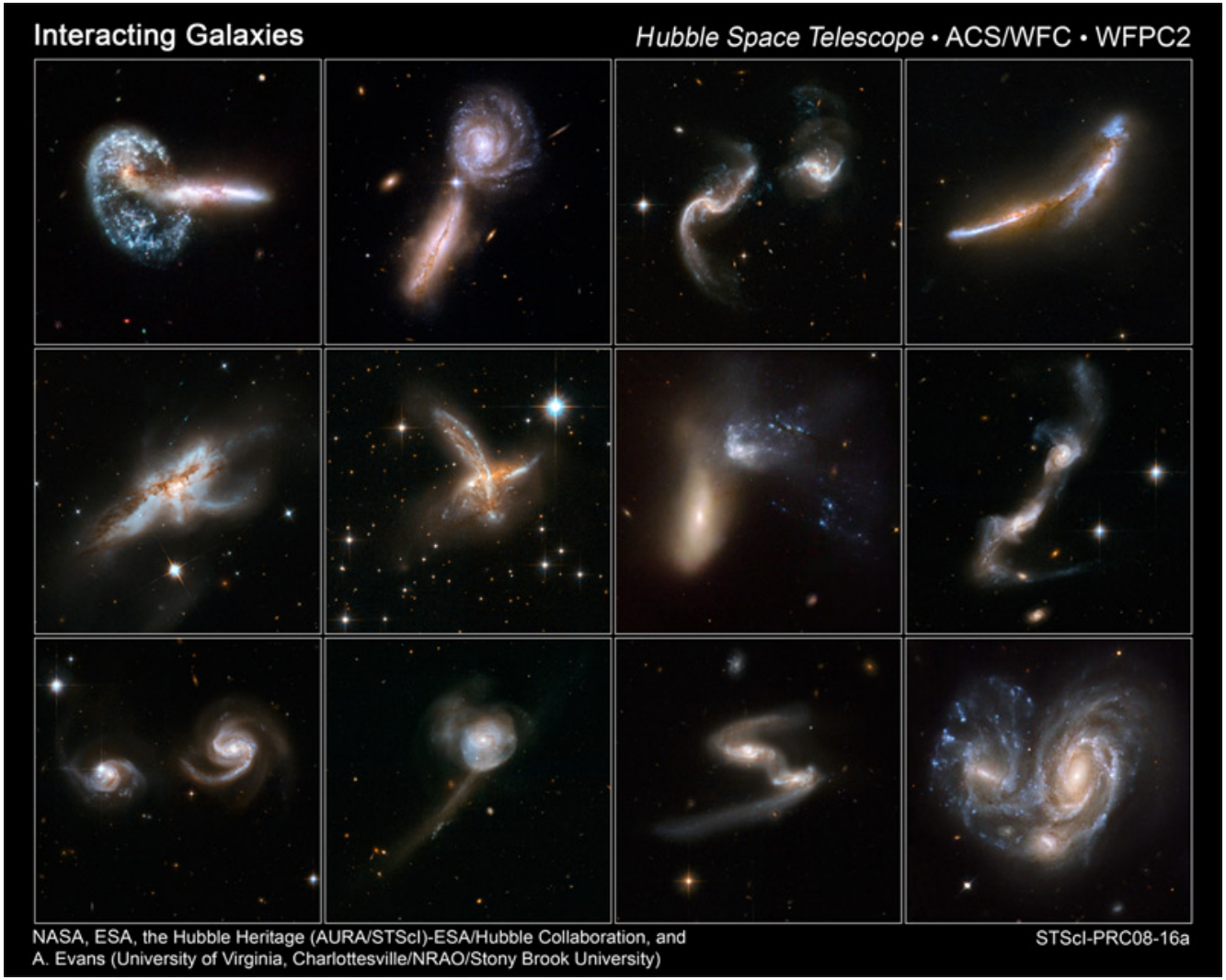

Figure: A few interacting galaxies

Freaks of nature

- There are a lot of "weird" galaxies
- In the 50's and 60's researchers postulated that these were colliding galaxies
- Toomre's models in the 70's were good fits with observations
- The discovery of dark matter halos gave galaxies larger cross sections

Basics of collisions

- Energy scale $\sim 10^{53}$ J $\sim 10^{8-9}$ supernovae
- This is of the order of the binding energy
- Timescales $\sim 10^{8}$ yrs
- We see only snapshots
- Most of the matter (dark+stellar) does not collide directly
- Gas does collide at supersonic speeds $M \sim 300$

Are collisions important?

- At first glance it seems that $\sim 1\%$ are colliding
- Models favor bound orbits rather than hyperbolic fly-bys
- Bound orbits+tidal distorions $\Rightarrow$ merger
- Collisions can funnel gas to the center of a galaxy, directly through tides and indirectly through induced spirals
- Toomre estimated that $\sim$ 10% of galaxies have merged in their past
- Galaxies are born in groups and are bound to each other $\Rightarrow$ collisions may be very common
- Merging may be a major part of the formation of an elliptical galaxy

Ring galaxies

- Rare, form after head-on collisions of two galaxies of similar size
- Important because we know a lot about the collision parameters
- During approach stars are drawn inward
- After the collision they rebound outward due to unbalanced centripetal force
- This happens faster in the inner disk so the stars will "meet" and form a compression wave
- Gas is compressed in a shock wave and star formation is higher in the wake

Ring galaxy

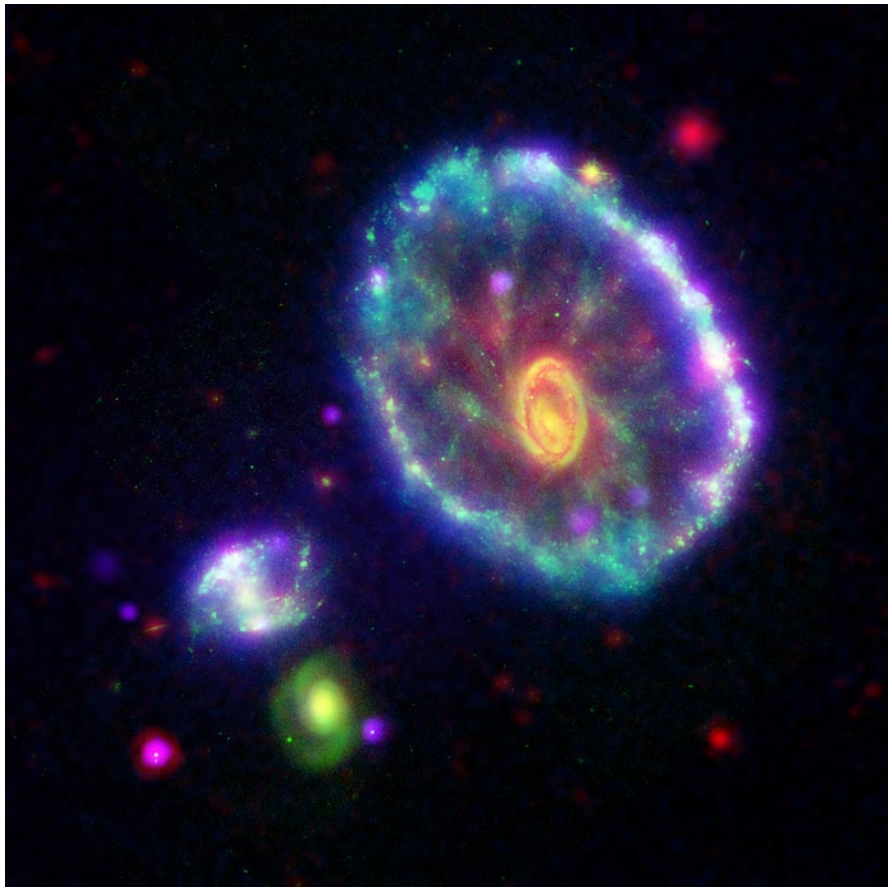

Figure: The cartwheel galaxy

Expanding rings

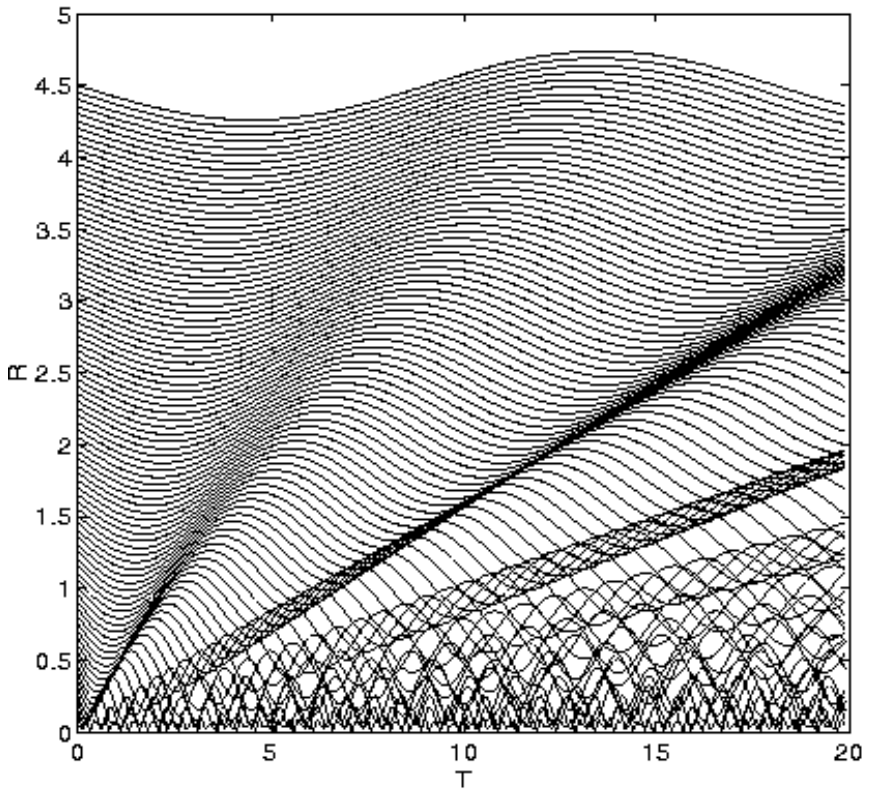

Figure: Radius versus time for representative stars

Spirals

- Prograde collisions in the plane of the disk can form spirals
- A leading spiral changes to a trailing one through shearing
- Swing amplification strengthens perturbations
- The spirals are generally short lived and dissipate in the inner Lindblad resonance
- The amplification depends on Q and $X = \lambda/\lambda_{\text{crit}}$
- λ is the pattern wavelength and λ_{crit} is the critical wavelength for gravitational instability
- The amplification is very sensitive to X $\Rightarrow$ few arms

Gravity Torque

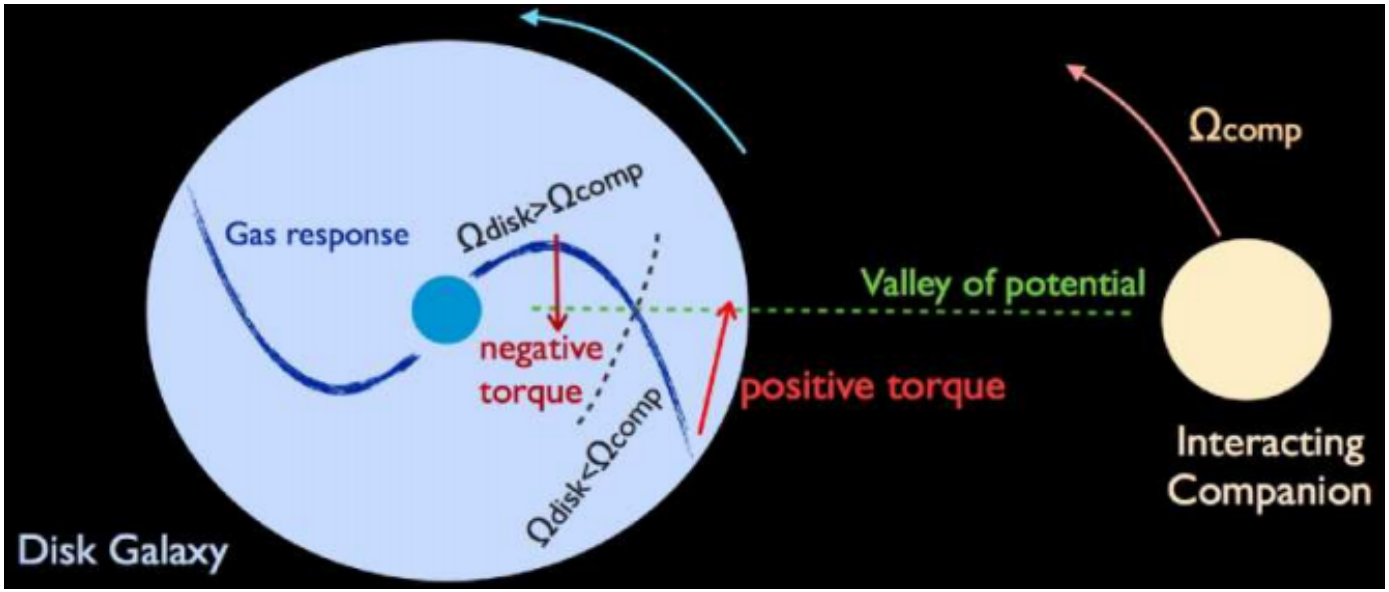

Figure: Inside the corotation radius there is negative torque while outside it the torque is positive

Tidal tails

- Tidal forces and torques often lead to the formation of tidal tails
- Material torn from the disk can pile up and become bound and star forming ($\sim 10^8 M_\odot$)
- These structures contain mostly of gas and new stars (old stars escape)
- Regions in the tails themselves can become instable and collapse
- The clouds/clusters have a typical Jeans length and mass

Beads on a string

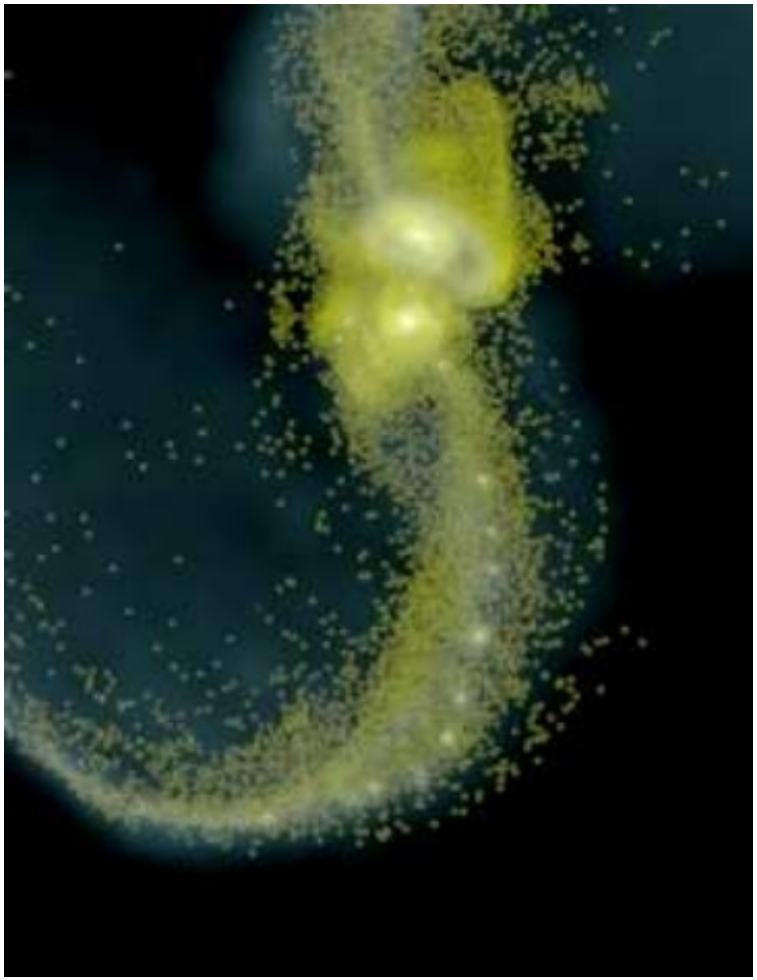

Figure: Massive star clusters in a tidal tail

Mergers

- It is now believed that merging is a major part of galaxy evolution
- Large cD galaxies in the center of clusters are probably the results of mergers
- Old galaxies formed through many small mergers early on
- Big eat small, cannibalism
- Mergers seem to have been more common in the past

Starbursts

- During a distant interaction e.g. early stages of a merger there is central gas inflow
- This increases the gas density and cloud collision rate $\Rightarrow$ starburst
- These are generally modest $\sim \times 3 - 4$ the premerger SFR
- The star formation takes place mostly in dense, massive clusters
- For two Milky Way sized galaxies we get $\sim 10^9 M_\odot$ new stars
- A large fraction of the new stars form in the nucleus and can form Kinematically Decoupled Cores
- In the very center the black holes are fed with lots of gas

A few closing points

- Modelling mergers is hard, we need a lot of objects and a lot of parameters
- Interaction between galaxies is a major part of galaxy evolution and star formation history
- Many galaxies may be the results of mergers, esp. ellipticals, cD
- Galaxy collisions are a hot topic

Extra: Galaxy Zoo

- http://galaxyzoo.org/
- Humans are better at identifying patterns than computers
- Galaxy Zoo volunteers classify galaxies online
- Statistical analysis can help our understanding of galaxies
- Volunteers are now able to simulate collisions of specific interacting galaxies

Galaxy Zoo: Mergers

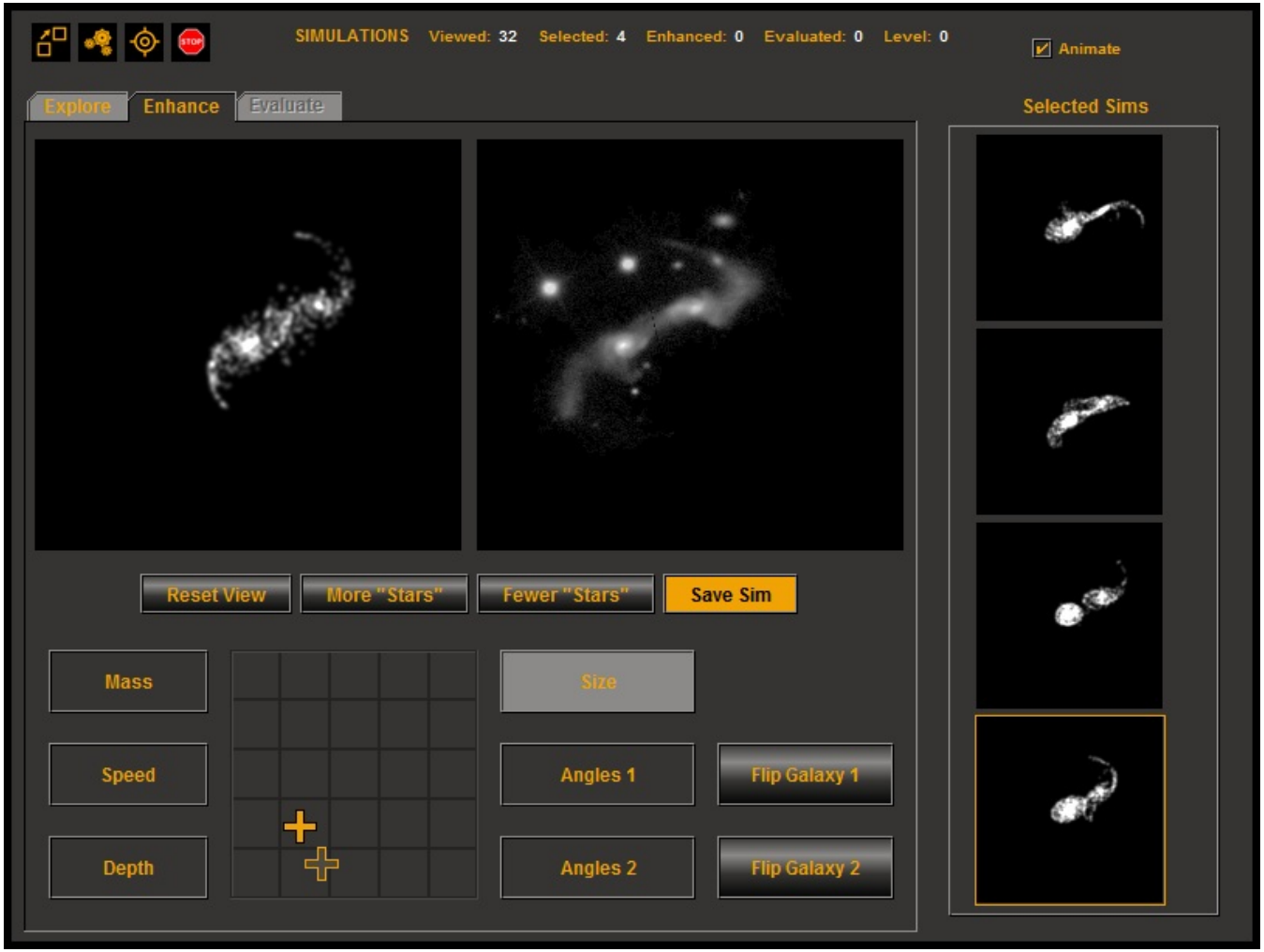

Figure: My try at modelling a merger