



Astro 301/ Fall 2006 (50405)



Introduction to Astronomy

<http://www.as.utexas.edu/~sj/a301-fa06>

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Lecture 21: Th Nov 16

Lecture 21: Announcements

- 1) Tue Nov 21 : Quiz 5 will be held and homework 4 will be given out in class
- 2) Exam 3 will be held on Dec 7.
There will be absolutely no make up exam under ANY circumstances.

Recent and Upcoming topics in class

Galaxies

Galaxy Types

How do we trace visible components in galaxies?

How do we trace dark matter components in galaxies?

Galaxy Interactions and Galaxy Mergers in the Present Day

Is our own Galaxy Interacting?

Starburst galaxies and active galaxies

How did galaxies form and evolve over 13 billion years

*Galaxy Interactions and Galaxy Mergers in the
Present Day*

Peculiar/Interacting Galaxies

Galaxies which look peculiar and distorted. These distortions are often caused by interactions with other galaxies.



Polar ring galaxy NGC 4650



Cartwheel galaxy
Head-on collision

Ring galaxy AM 0644-741 50,000 ly across



Galaxy Interactions vs Galaxy Mergers

1) How do two separate galaxies interact?

Via the force of gravity between their mass

2) What determines whether 2 interacting galaxies will end up merging into one system or fly by each other?

Competition between the force of gravity trying to bind them, and their relative speed of motion with respect to each other.

It is harder to merge galaxies moving with large speeds with respect to each other.



Physical Processes During Galaxy Mergers

1) Force of gravity

- Acts on stars, gas and dark matter.
- Tries to merge galaxies
- Produces tails of gas and stars
- (Can lead to a process called violent relaxation in the case of major mergers)



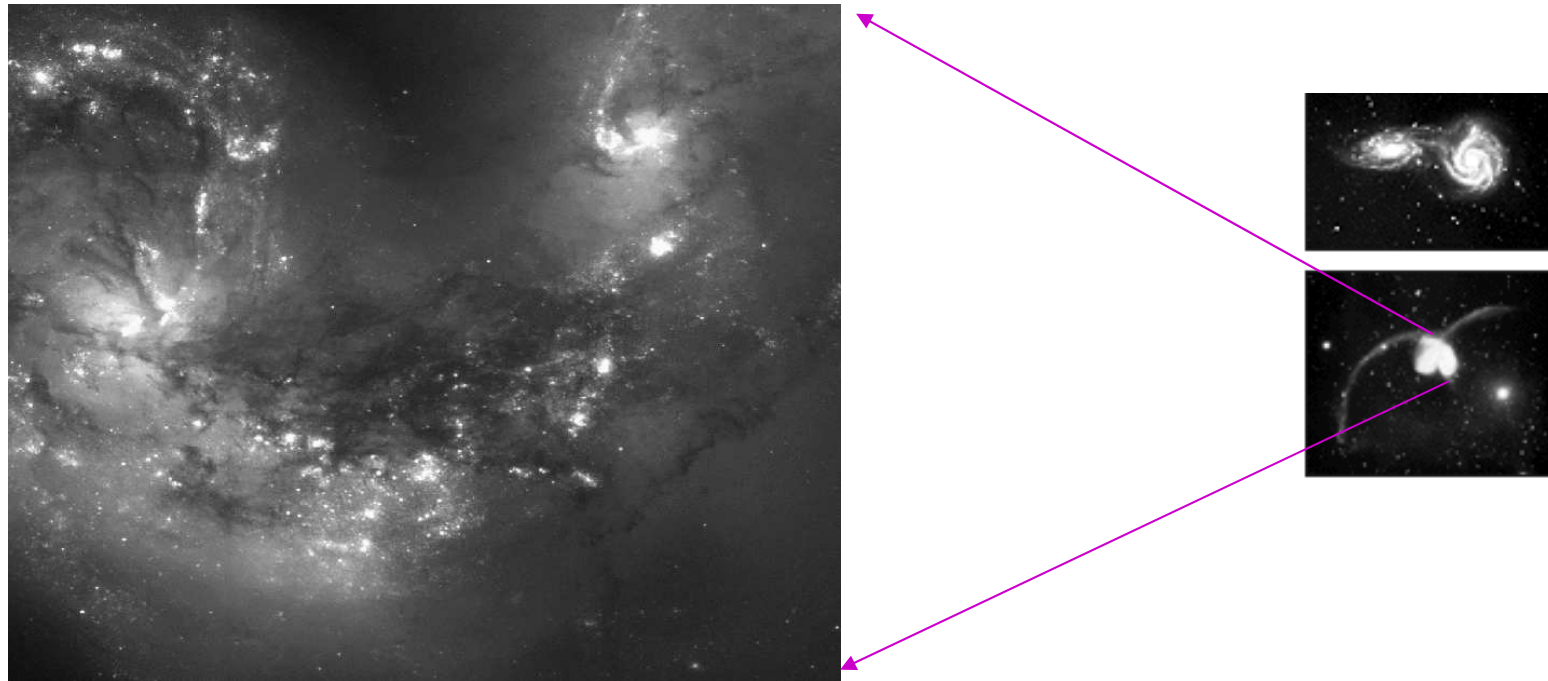
2) Why don't stars collide during a galaxy merger?

- Size of a star ($\sim 7 \times 10^8 \text{ m}$) is much smaller than separation ($1 \text{ pc} \sim 3 \times 10^{16} \text{ m}$) between stars.
- Stars experience the force of gravity, but do not experience shocks

3) Why do gas particles collide with each other during a galaxy merger?

Gas acts like a fluid: it collides, experiences shocks, and radiates away (loses) energy.

Physical Processes During Galaxy Mergers



4) How do we form new stars during a merger ?

- à gas is compressed to high density (by what?)
- à at high density, the force of gravity wins over opposing forces (which?)
- à the dominant force of gravity makes gas collapse to form new stars

5) What is the fate of the new stars?

- Massive stars die in a few 10^6 to 10^7 years.
So they are only seen in regions of recent star formation
- Low mass stars can survive 10 Gyr or longer

Major Mergers

A major merger refers to the merger of 2 disk galaxies (spirals, Irr, dwarfs) with similar masses such that their mass ratio is in the range 1/1 to 1/3.

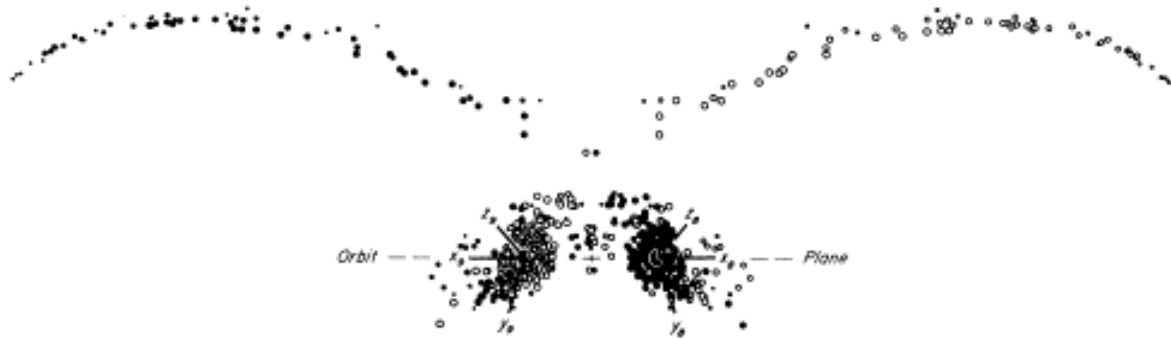
Such a merger **will destroy the disks of both galaxies and eventually produce a 3-D spheroidal system** that resembles a giant bulge or an elliptical galaxy.

The transformation from flattened disk systems to 3-D spheroidal systems happens due to a process called violent relaxation.

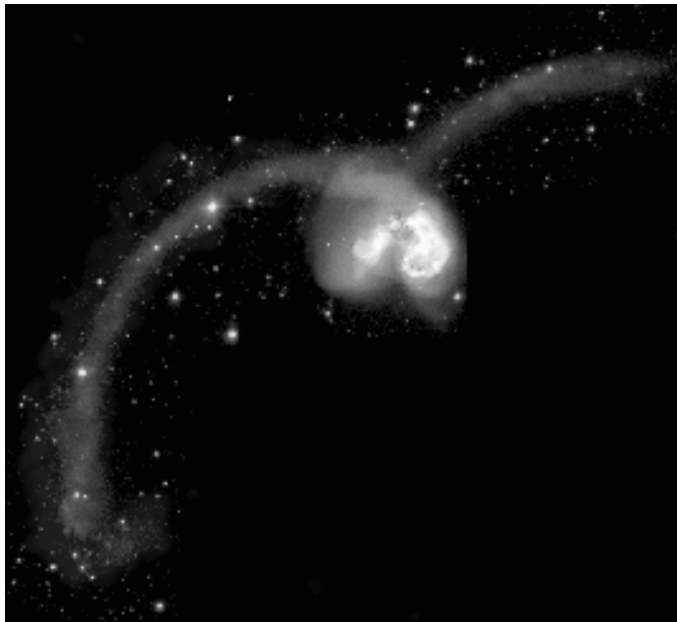
Violent relaxation

- à kicks in when the force of gravity acting on stars is large and changes rapidly with time.
- à makes stars in the two spirals “lose memory” of their disk distributions and move equally in all directions, thereby forming a 3-D spheroidal (water-melon) configuration.

Simulations of the major merger of 2 spirals

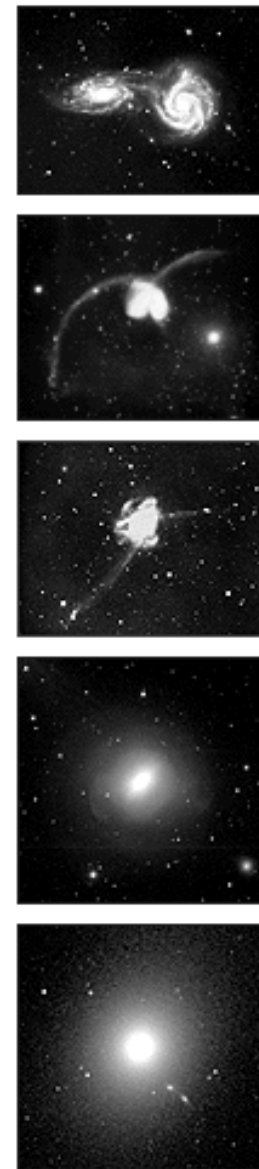


Computer simulation of 'Galactic bridges and tail' by Toomre & Toomre 1972



Observation of stars (green) and HI gas (blue) in NGC 4038/39 called The Antennae galaxy.
(J. Hibbard)

Simulation of Major Merger of 2 disk galaxies



Merger of 2 spirals of similar mass destroys the disks and produces an elliptical galaxy!

Stages in a Major Merger

The Toomre sequence is a sequence of observed galaxies which are believed to be in different stages of a major merger between 2 spirals.



Credit: Vera Rubin (CIW/DTM)
NGC 5426/5427



Credit: Francois Schweizer (CIW/DTM)
NGC 4038/4039



Credit: Francois Schweizer (CIW/DTM)
NGC 7252



Credit: Francois Schweizer (CIW/DTM)
NGC 3610

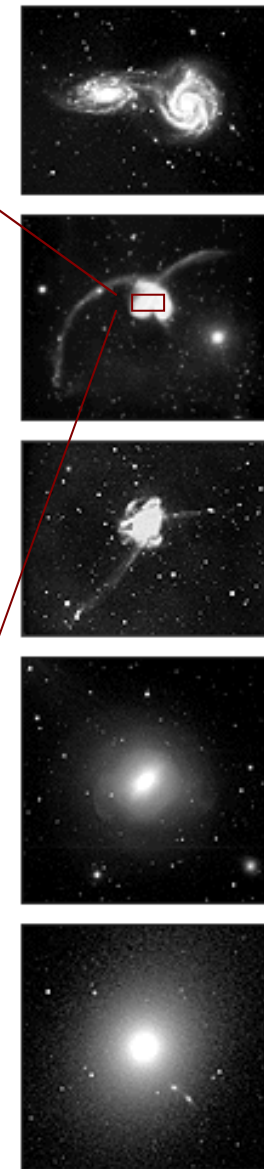
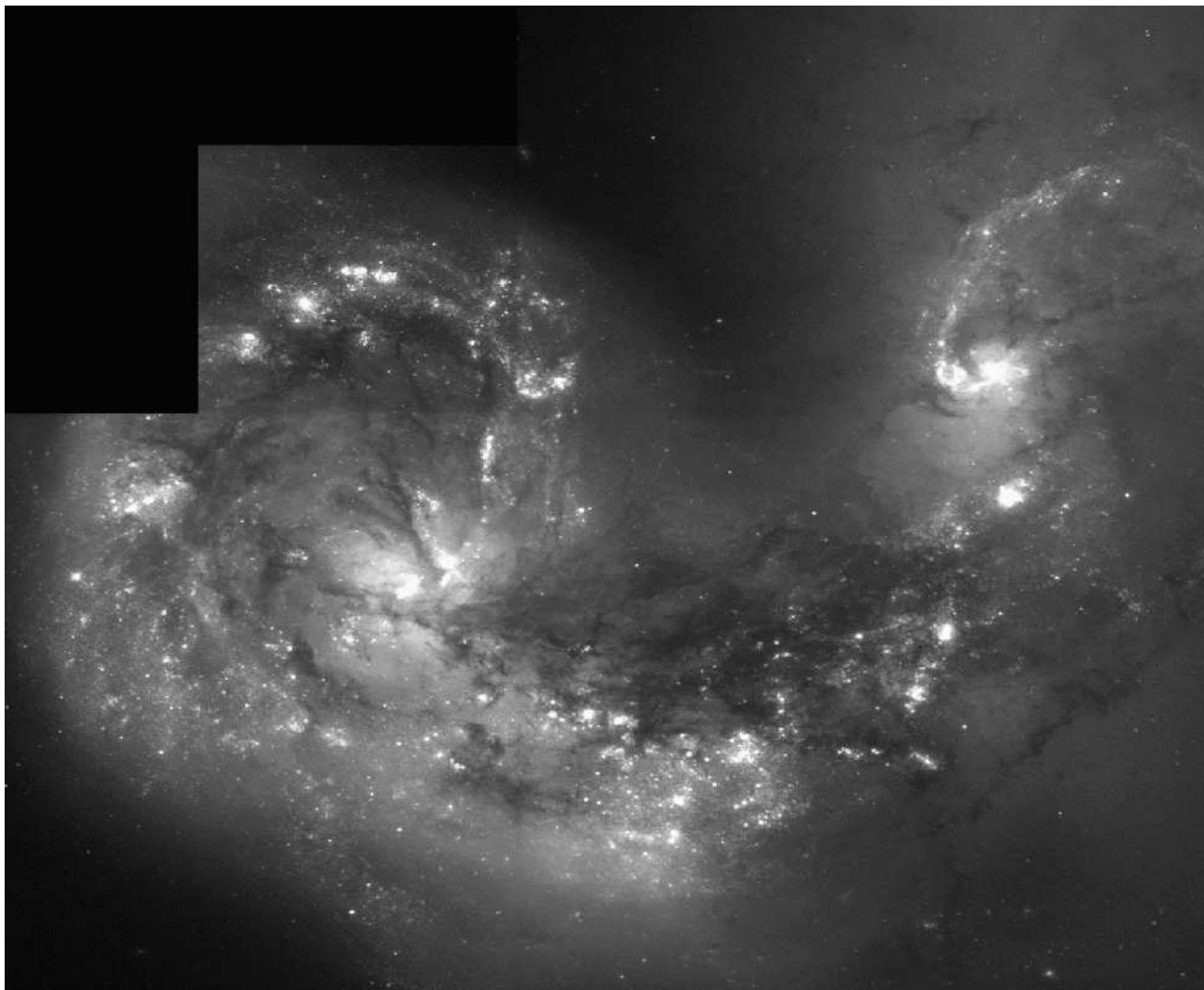


Credit: Digitized Sky Survey (AURA, Inc.)

When 2 spirals of similar mass merge:

- 1) Gravitational forces fling out gas and stars into two extended tails. The similar length of the two tails 'reflects' the rotation of the two disk galaxies of similar masses.
- 2) The stars in the tails fade away, while gas in the tails falls back into the galaxies to form stars.
- 3) The disks are destroyed via a process called violent relaxation. Violent relaxation makes stars in the two spirals "lose memory" of their disk distributions and redistribute into a spheroidal (water-melon) configuration
- 4) End-product is an elliptical galaxy

The Toomre Sequence



The Antennae system is part of the Toomre sequence on RHS
The HST image shows the central region only: it confirms the presence of 2 disks with gas stripped out

Minor Mergers

- Minor merger

A minor merger refers to the merger of 2 galaxies with widely different masses such that their mass ratio is lower than $1/4$ (e.g., $1/5$, $1/10$, $1/100$)

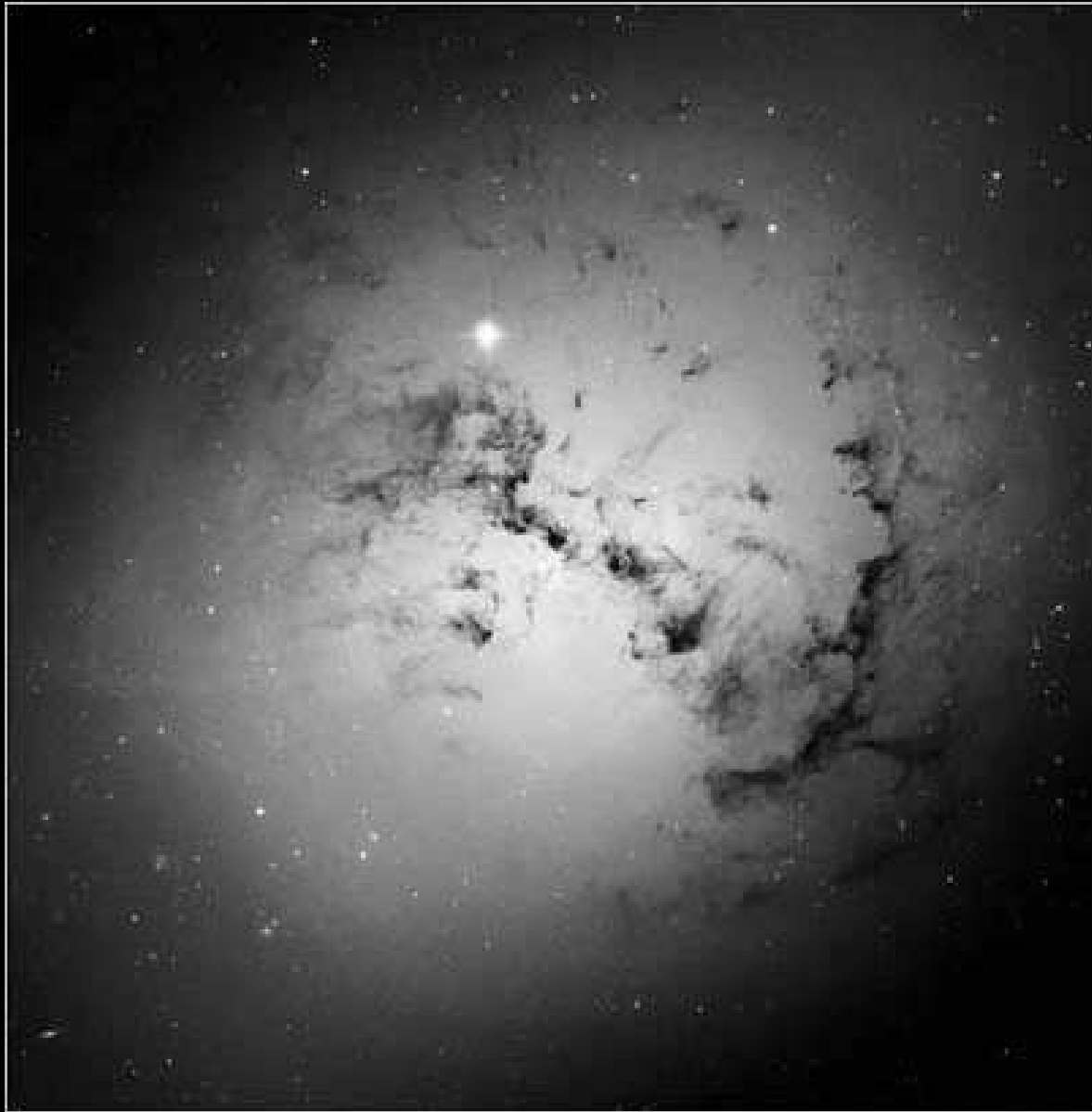
The disk of the larger will not be destroyed in a minor merger. However, it will likely show distortions such as ripples, arcs, tails

The smaller galaxy may be tidally ripped apart by the interaction and its constituents (stars, gas, dust) scattered as debris within the larger galaxy or as tails around the larger galaxy.

QFS; Why does violent relaxation not take place in a minor merger ?

Minor mergers

Elliptical Galaxy NGC 1316



The elliptical galaxy (NGC 1316) has recently cannibalized smaller spiral galaxies which are 1/10 to 1/100 its mass, and have lots of gas and dust

NGC 2782: What type of merger is this?



The visible light image shows
- a relatively undisturbed disk
- a 20,000 pc tail to the left

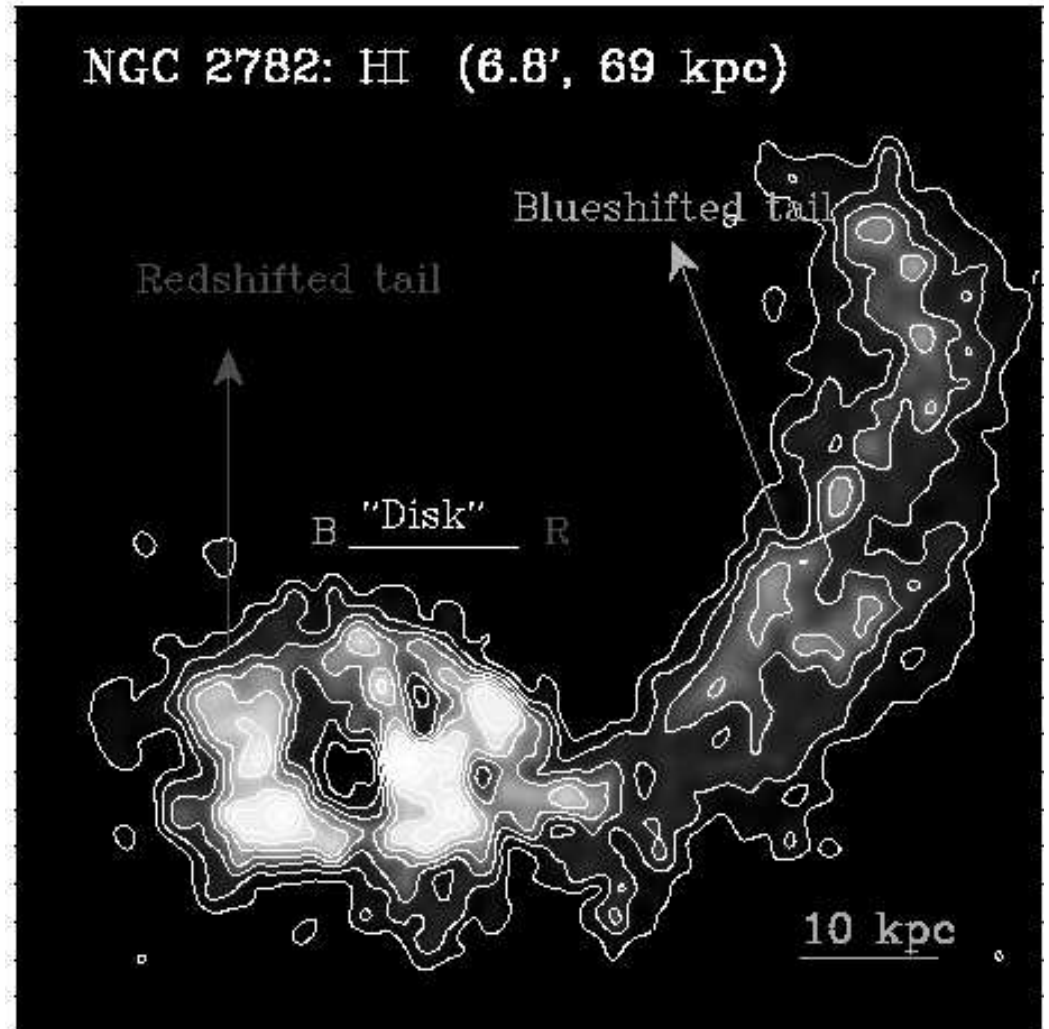


Image at 21 cm (atomic H) shows the disk and
a HUGE 50,000 pc tail to the right

Is our own Galaxy Interacting?

Is our own Galaxy Interacting?

- The Milky Way, is part of the Local Group, a set of ~40 galaxies that are bound by gravity. (Includes 3 massive spirals, 4E/dEs, 17 dwarfs dSph, 12 dlrr/lrr).
- 90% of the luminosity of the local group come from 3 massive spirals
M31 (Andromeda SAb), Milky Way (SBbc), M33(SAcd)
- Closest neighbors of the Milky Way are Sagittarius (dwarf), LMC (lrr), and SMC (lrr)
Sagittarius (dE): 0.08×10^6 lyr ; LMC (lrr) : 0.16×10^6 lyr SMC (lrr) , distance = 0.19×10^6 lyr



LMC; lrr; 30,000 ly across



SMC; lrr ;18,000 ly across

The Milky Way (an SBbc galaxy) is currently undergoing several interactions

à It is presently 'digesting' the Sagittarius (dwarf elliptical) galaxy_.

à It is interacting with SMC (Irr) and LMC (Irr) producing the Magellanic bridge of atomic H

à It has a warp and this may be due to a past accretion of a satellite

In the future,
there is at
least one
more coming

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à The Milky Way is moving at 83 km/s toward M31 (Spiral SAb) located 2.5 million ly away.

à See Lect 4 + hwk 6: what type of merger will this be? When will it occur?

