Look at the (relatively) nearby galaxy M82:

It is a small galaxy with a system of filaments emanating from the center. These filaments are most prominent when observed in Hα, meaning they are filaments of ionized gas:

What is happening in this galaxy? At first, people though some sort of titanic explosions were ripping the galaxy apart. This is partly right — there are titanic explosions occurring in the center of M82, but they are not destroying the galaxy. They are supernovae, and we now know M82 to be a starburst galaxy.

A starburst galaxy is a galaxy which is experiencing a brief (10^7-10^8 year) burst of intense star forming activity. During these bursts, the star formation rate per unit area can be 10 or 100 times greater than the star formation rate in normal spiral galaxies — the star formation rate of M82 is similar to that of the (non-starbursting) Sc spiral M101, yet the sizes are very different.

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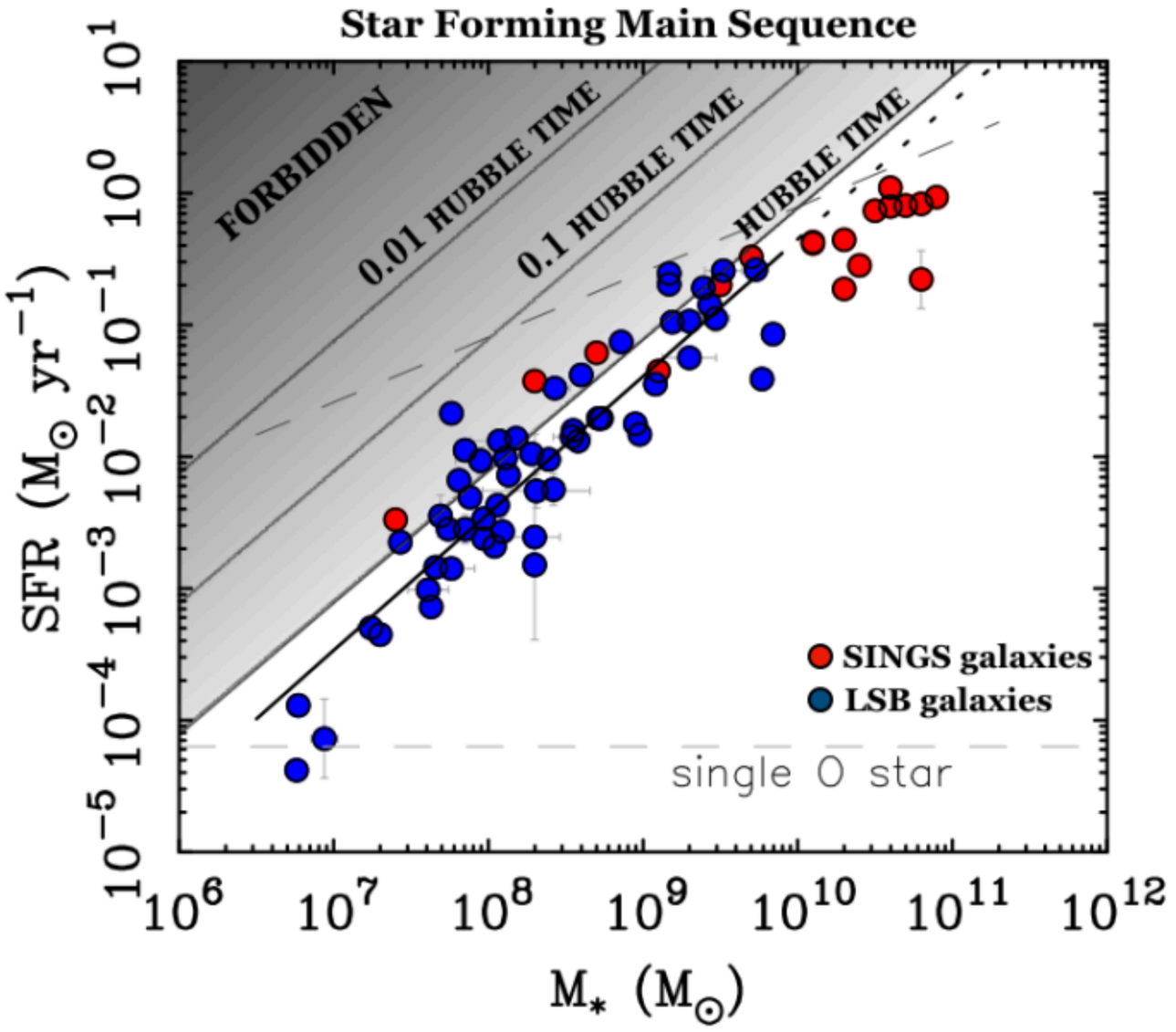
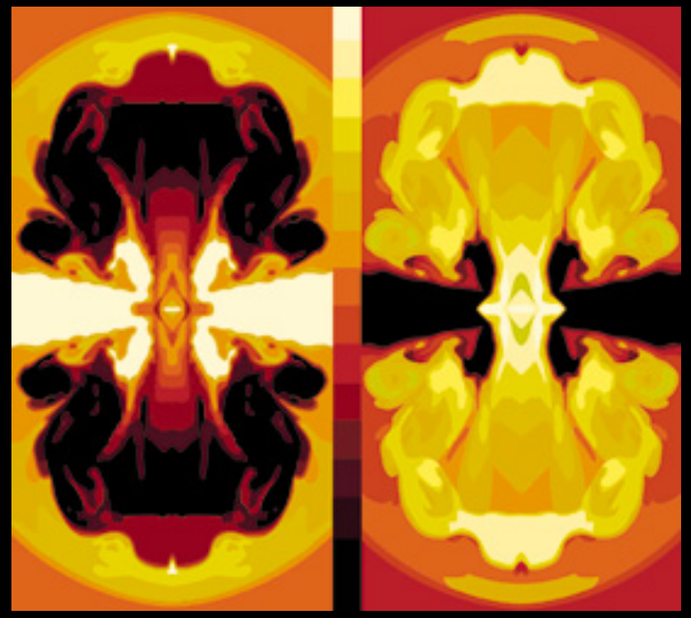
Starburst galaxies are producing stars at rates well in excess of what is normal for regular star forming galaxies (adapted from McGaugh+ 2017):





Density Temperature

In a starburst galaxy, many massive young stars are formed, making the galaxy very bright and very blue. These massive stars also play havoc on the interstellar gas, heating it through stellar winds and supernovae, and can heat the gas to millions of degrees. This hot gas can flow out of the galaxy as a starburst wind. We can see this gas as the ionized filaments as well as in X-rays.

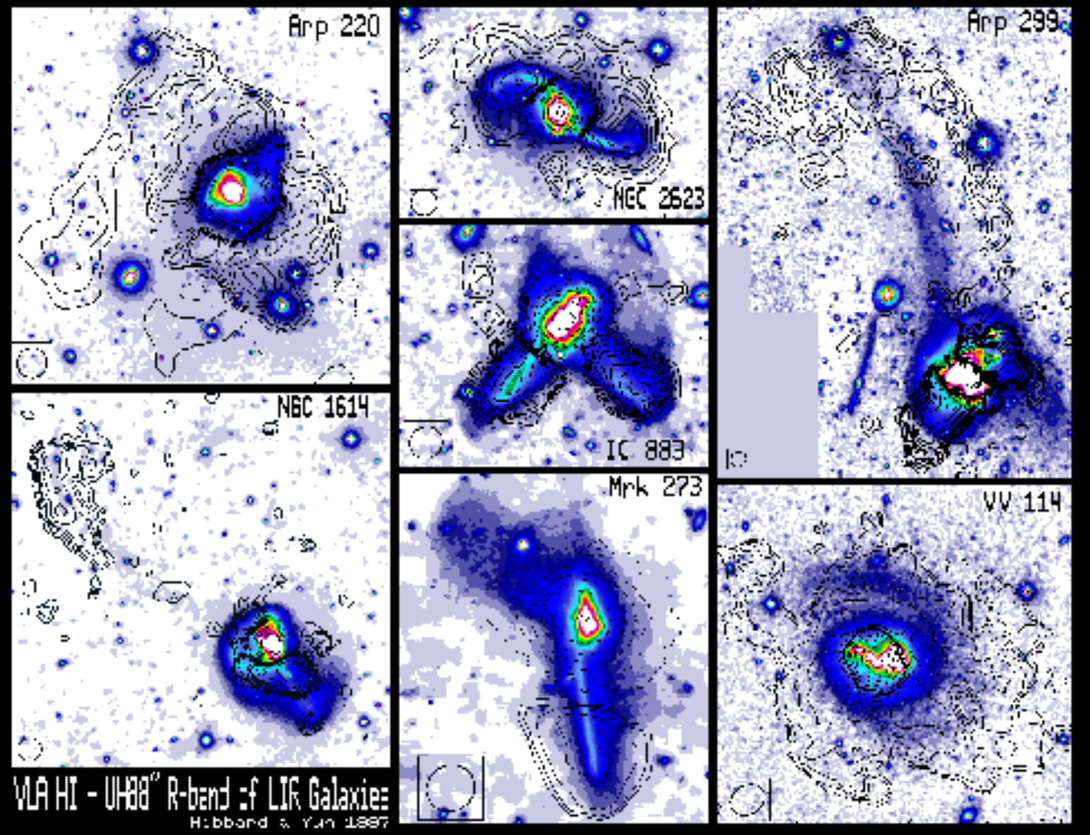
M82 in X-rays (from the Chandra satellite), showing the very hot outflowing gas:

Question: why would the starburst phase be short? (How long would they take to use up all their gas?)

Starburst galaxies are not only bright and blue, but they are typically very dusty. Lots of gas, lots of dust, right? And what does dust do?

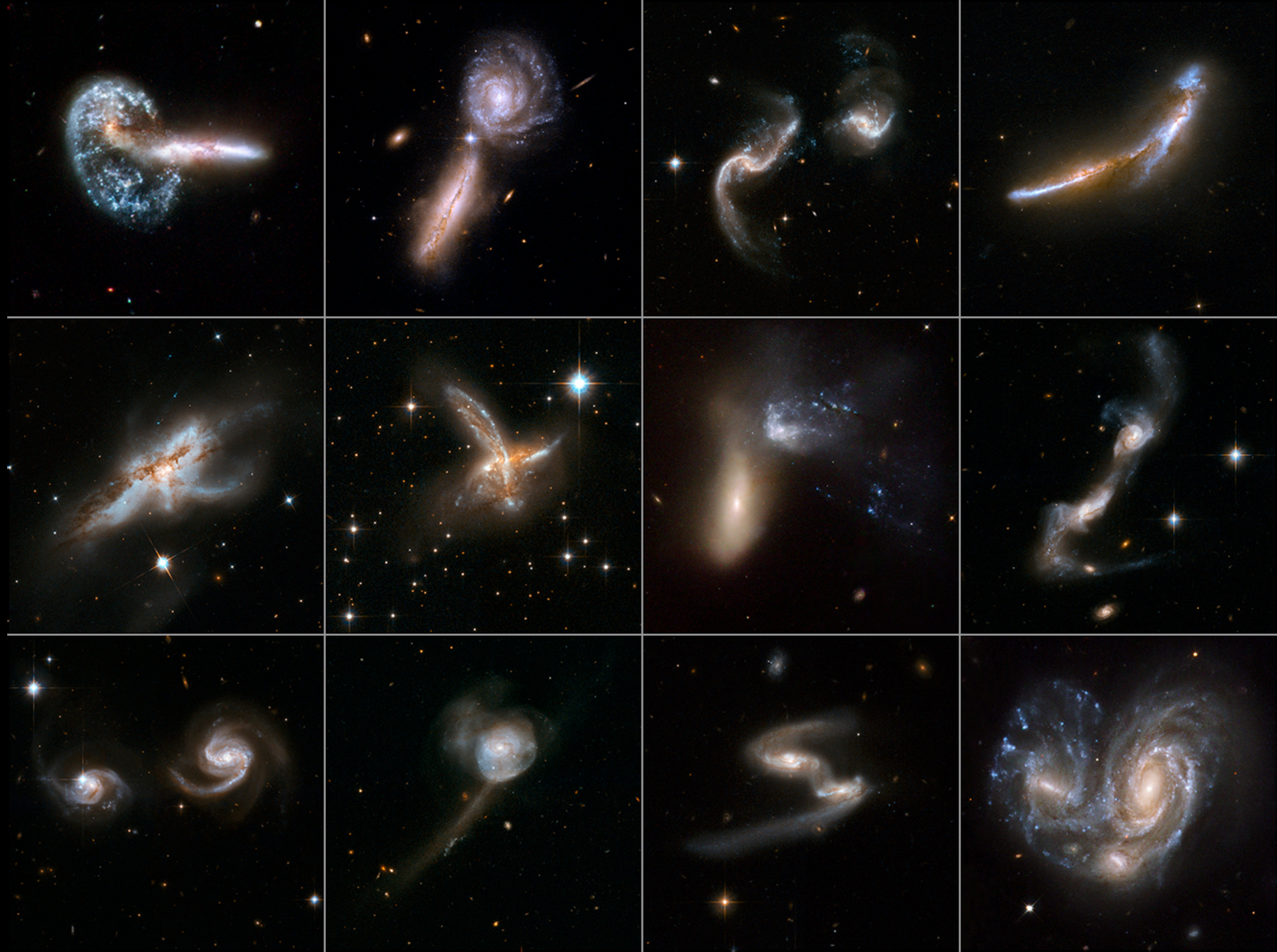
If dust is absorbing the light from the young stars and blocking us from seeing in the optical, that dust must heat up and emit infrared radiation. *Starburst galaxies should be infrared bright*.

In 1983, an infrared observing satellite was launched (IRAS). One of its jobs was to search for infrared bright starburst galaxies — and it found lots.



Ultraluminous IRAS Galaxies. Bright in the infrared, with luminosities > 10^{12} L_{sun}
So luminous, in fact, that it is being argued whether or not star formation alone can power these galaxies — maybe black holes are accreting material and providing luminosity as well.

What do these galaxies look like?
As we see, these all show signs that they are or have been involved in interactions (and even mergers) with other galaxies. *Interactions somehow cause starburst activity!*




M81, M82, and NGC 3077 / Don J. McCrady / 30-Oct-2006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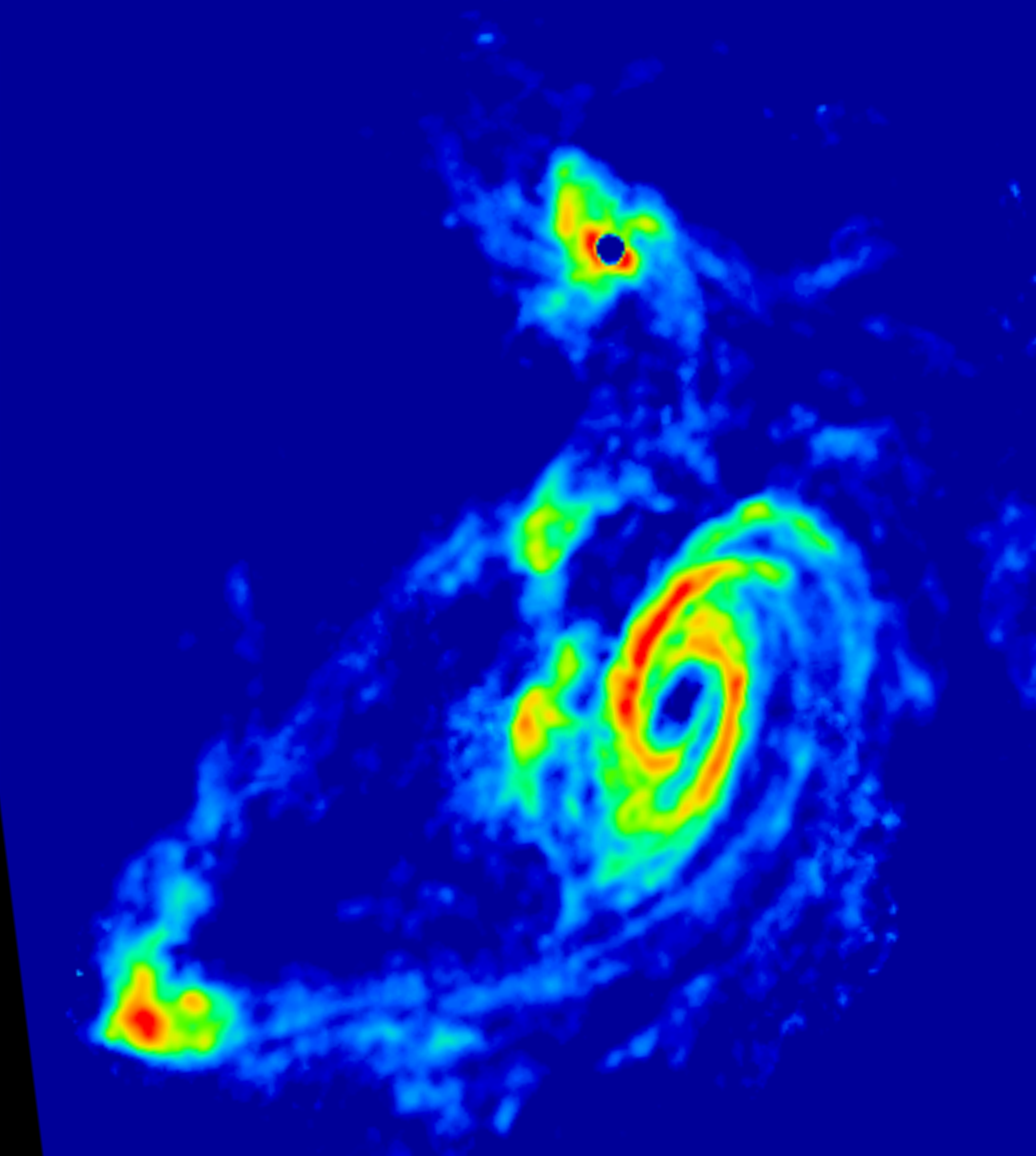


When we look in the sky, we see many galaxies which come in pairs and are often morphologically very peculiar. Time scale for major interactions ~ 500 Myr - 1 Gyr or so.

Can't watch individual galaxies collide and evolve; to understand how they change, we need to rely on

- "snapshots" of many colliding galaxies
- computer simulations of colliding galaxies

But *why* do galaxies merge? Galaxies can orbit each other just like comets orbit the sun. Comets don't spiral into the sun, but galaxies can spiral together to merge. What's the difference?

Why don't comets spiral into the Sun?

Why do low-orbit satellites eventually spiral in towards the Earth?

How does this relate to merging galaxies?

Imagine a massive object moving through a background "sea" of low mass objects. As it moves through, it creates a trailing "wake" -- an excess in the density of the low mass objects behind it.

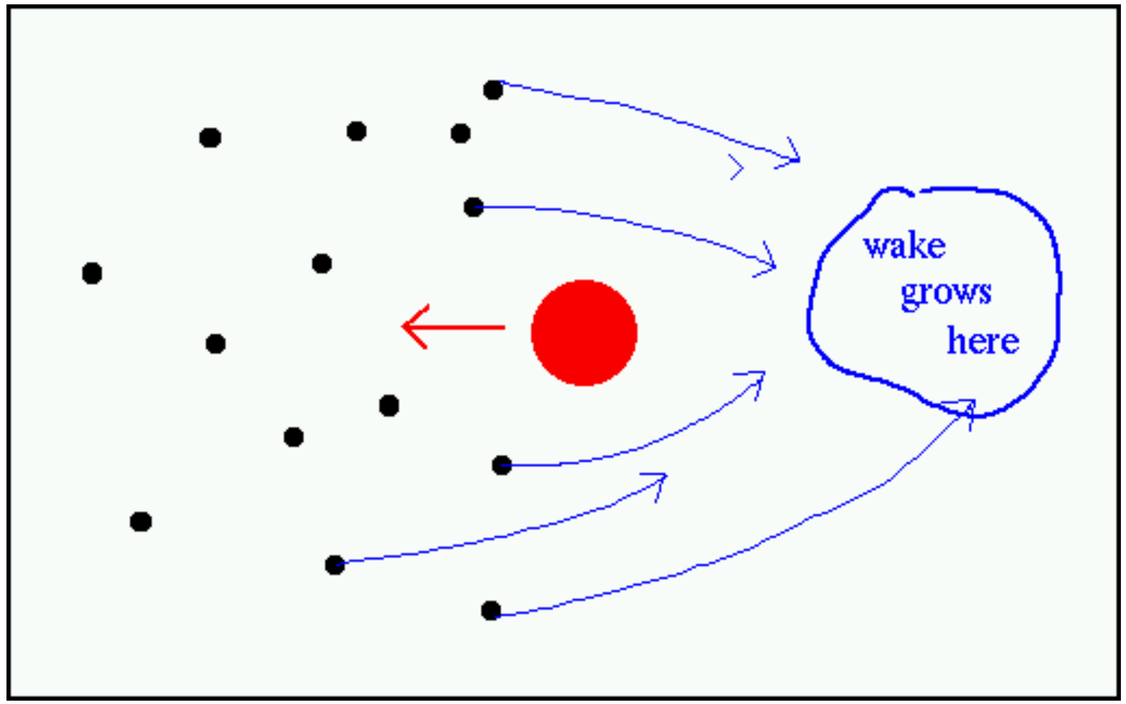
Why would this act like a frictional force in the motion of the massive object?

What is the massive object?

What is the sea?

So as galaxies move through each other, they feel a frictional force that causes their orbit to decay, and they merge. Put differently the energy and angular momentum of the galaxies orbit gets transferred to the internal energy and spin of the dark matter halos (and to the galaxies' stellar parts, too).

Starbursts: When galaxies interact and merge, their interstellar gas can be compressed and driven to the inner regions through shocks and gravitational torques, triggering intense starbursts.



And whats's with these tails? Think back to gravitational tidal forces: they act to radially stretch anything passing near a massive object. Couple that with the fact that galaxies are only bound by gravity, and that they are rotating, and we can see that tails for from material "spun off" by gravitational forces during collisions.

The shape of tails can be affected by:

- Mass ratio of the two galaxies
- Time since interaction
- Encounter/disk geometry
- Viewing angle

Therefore, the tails hold a "archeological record" of the encounter, although they can be tricky to decipher