Astronomy 150: Killer Skies
Lecture 34, April 20

Assignments:

- HW10 was due at start of class
- Computer Lab 2 due today
- ICES available online
- HW11 due next Friday: last homework!
  - note: lowest HW score dropped
  - but: HW11 material will be on Exam 3, so be sure to look at it

Last time: Our Milky Way Galaxy

Today: When Galaxies Collide

ICES

ICES course evaluation is now available, done online.

Please do it!

- **Written comments are the most useful and important**
- **I do read the comments, and I do modify the course as a result.**
- **Note that this course is relatively new, so your comments will have a particularly large impact.**

Have you gotten the email from ICES?

A. yes, and I plan to do it

B. no, but I will do it by going to

https://ices.cte.uiuc.edu/

Recap: Galaxies

stars are not evenly distributed everywhere, but occur together in galaxies

Galaxies: What Meets the Eye

- massive objects bound together by gravity
- "ecosystems" where star formation occurs and thus gas is cycled into and out of stars
- the "building blocks" of the universe

Galaxy Diversity

- galaxies span a wide range of size and mass
- from small, low-mass "dwarf" galaxies
- to huge, massive "giant" galaxies
- galaxy come in several basic varieties
  - spiral: disk of stars and gas and dust, spiral arms, ongoing star formation
  - elliptical: no dust and no cool gas, no ongoing star formation, no disk, round shape
  - irregular: gas, stars, and dust all present; no simple shapes

Galaxies: Gravity and Mass

- galaxies have mass and thus gravity
- stars and gas are accelerated: move in orbits
- orbit speed patterns (rotation curves) reveal galaxy gravity and thus total mass
- results:
  - our Milky Way Galaxy has much more mass than is seen in stars & gas
  - other galaxies also have more mass than is seen in visible light
- all galaxies mostly made of dark matter!
- dark matter fills the universe!

Galaxies Fill the Universe

Galaxies are building blocks of the universe.

- How are they arranged in space?

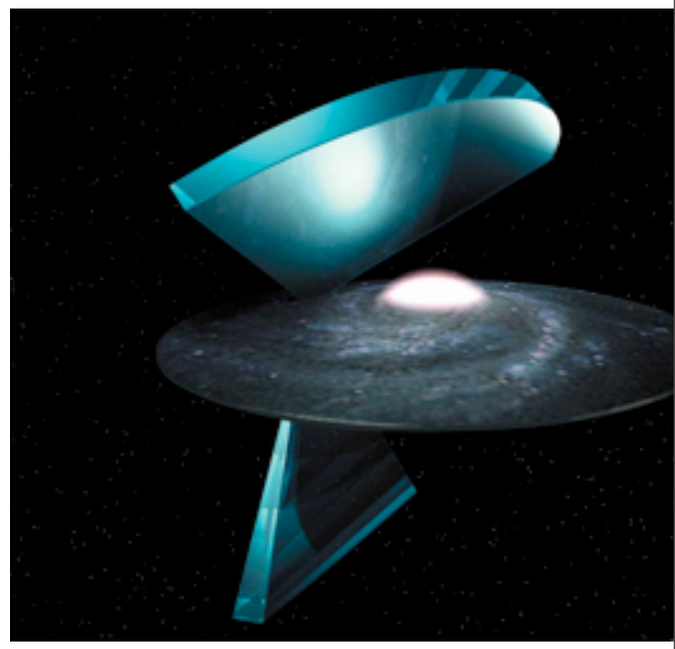
Experiment: look beyond our Galaxy and map other galaxies throughout space

- for example: swing telescope across two regions of sky ("pizza slices")

Vote your conscience:

What will the galaxy map show?

A. galaxies will be found everywhere, randomly located
B. galaxies will be clumped together
C. galaxies will be found in all directions
D. more than one of the above
E. none of the above



Slices of the Universe

Map construction:

- center of "pizza" = our location
- each dot: location of one galaxy

Focus on the innermost half of the region

Squint: focus on large-scale features

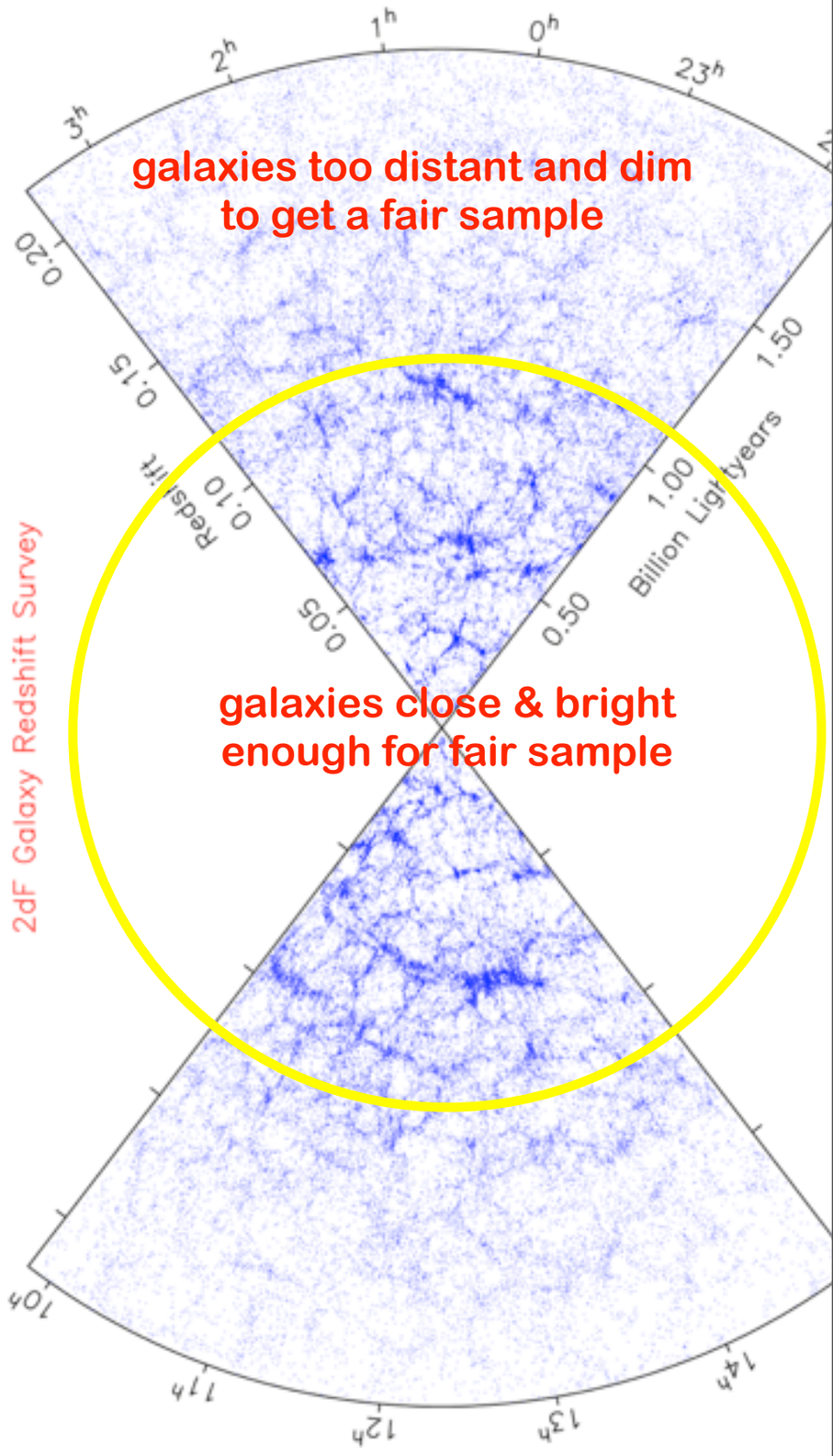
- galaxies smoothly and randomly fill space
- not all located in one place
- not all avoiding some other place

Look closely : focus on small-scale features

- on small scales, galaxies fill space unevenly
- some regions almost empty: "voids"
- some have a few galaxies near each other: "groups"
- some have huge numbers of galaxies in small region: "rich clusters"

What about most distant regions?

- galaxies so far away, can't see a representative sample
- looks like running out of galaxies, but really just seeing brightest ones: tip of the iceberg



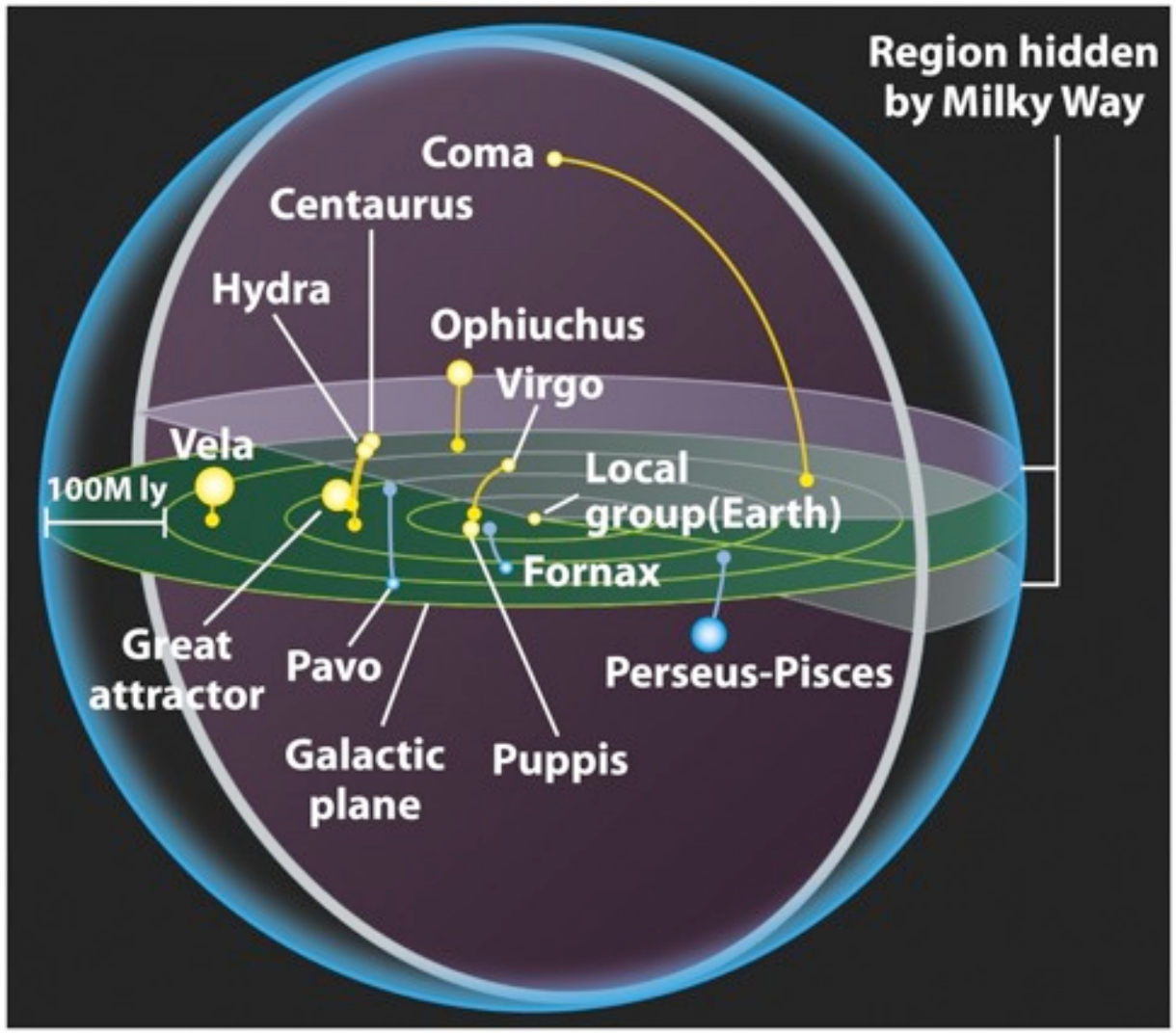
Galaxies Are Not Alone

Galaxies are not scattered randomly throughout the Universe

Galaxies are found in clusters

Like clusters of stars, clusters of galaxies come in a wide variety

- Poor or rich?
  - Dozens or thousands of members?
- Regular or irregular?
  - Is the cluster concentrated towards the center?



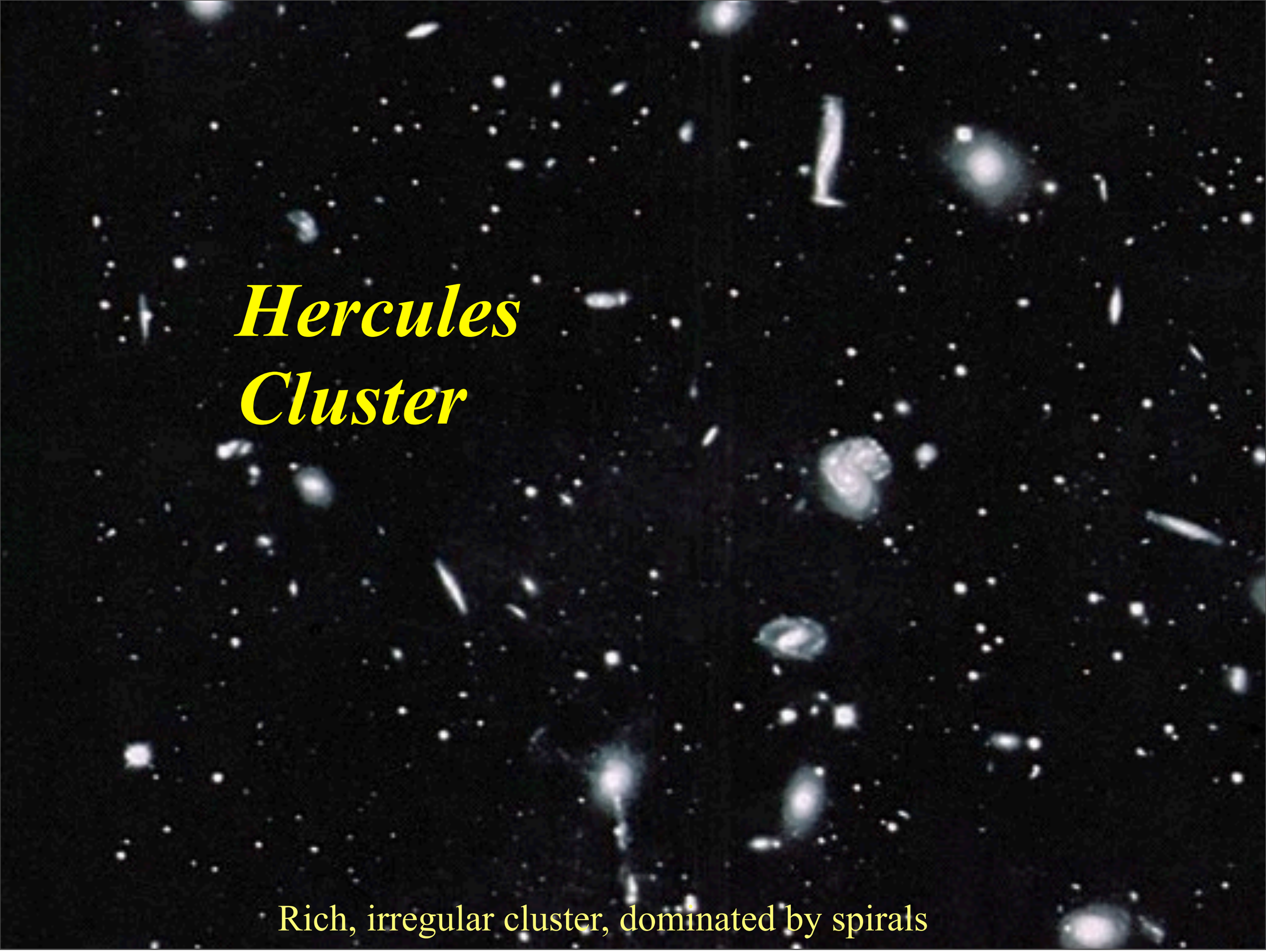
800 Mly sphere, centered on Earth

Galaxy Clusters

- Large, rich clusters often contain **giant elliptical galaxies** at their centers

Abell 2218, a large galaxy cluster

Fornax Cluster


Hercules
Cluster
Rich, irregular cluster, dominated by spirals

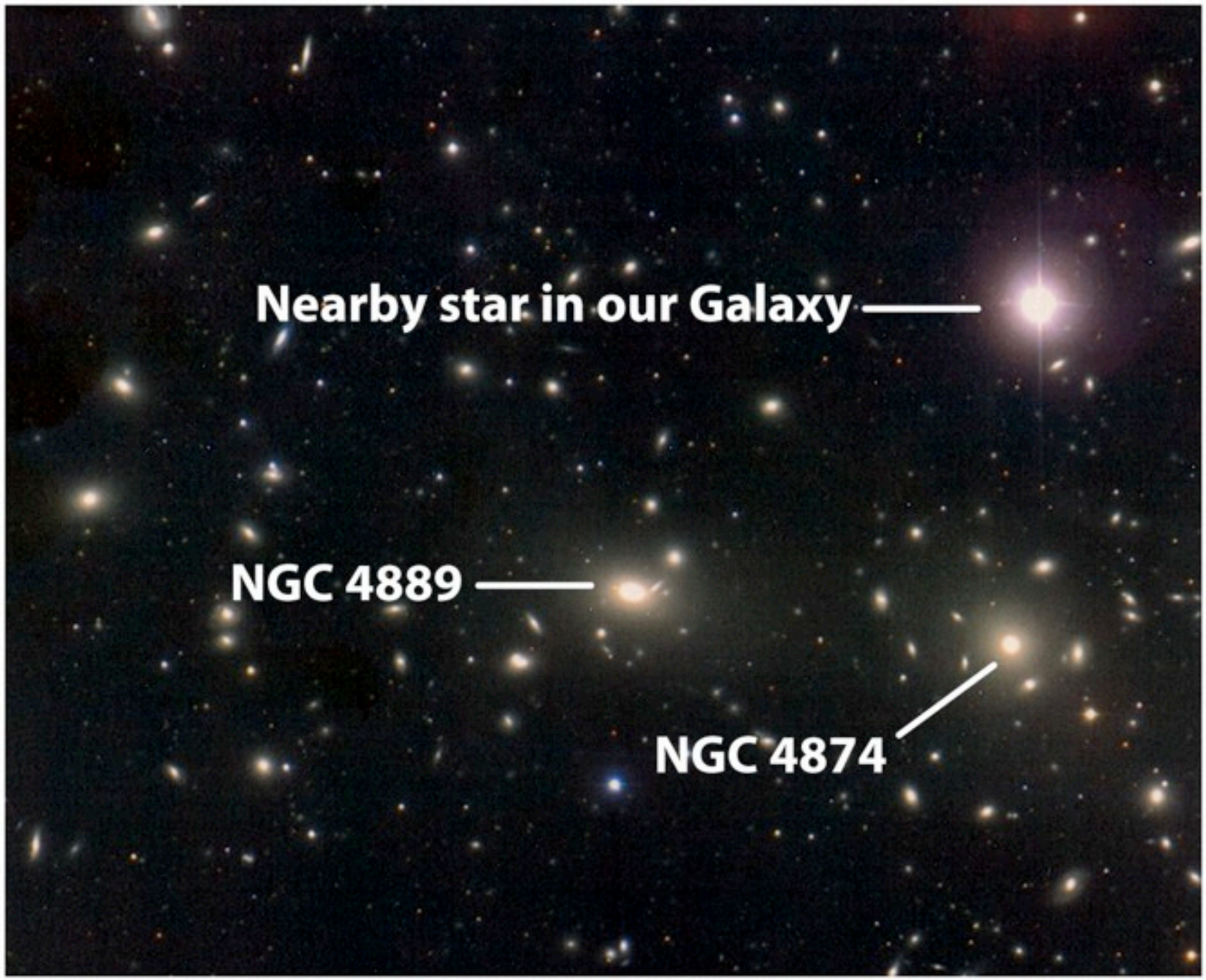
The Coma Cluster

Rich, regular cluster

90 Mpc = 300 million lyrs.

Over 2000 galaxies.

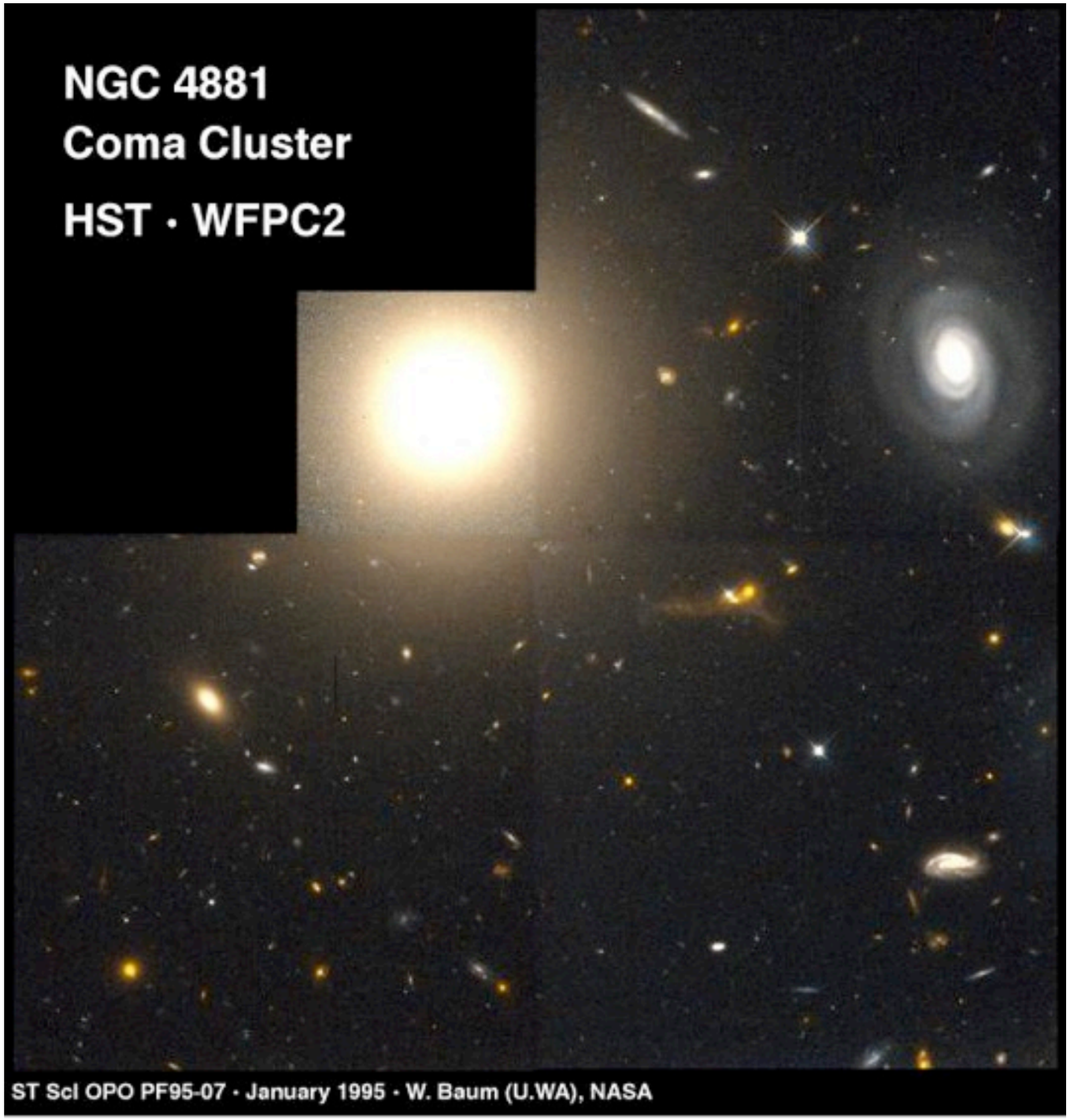
Dominated by two ellipticals



Coma Cluster

A zoom near one of the ellipticals

Contains many spirals, but more ellipticals the closer to the center




Virgo Cluster

The Virgo Cluster

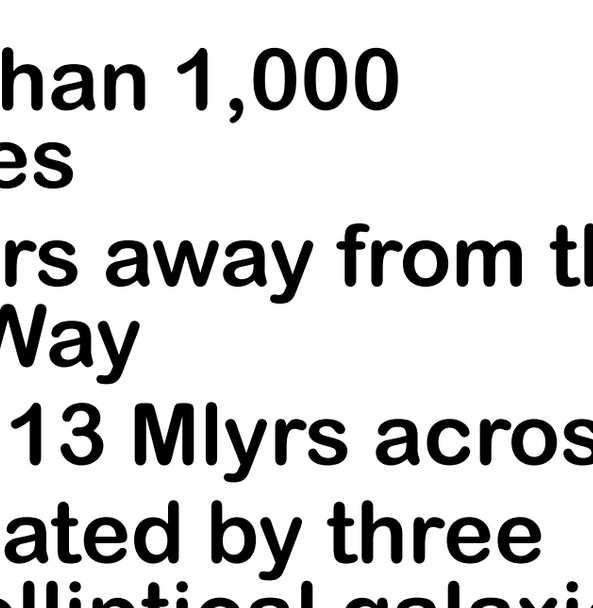
More than 1,000 galaxies

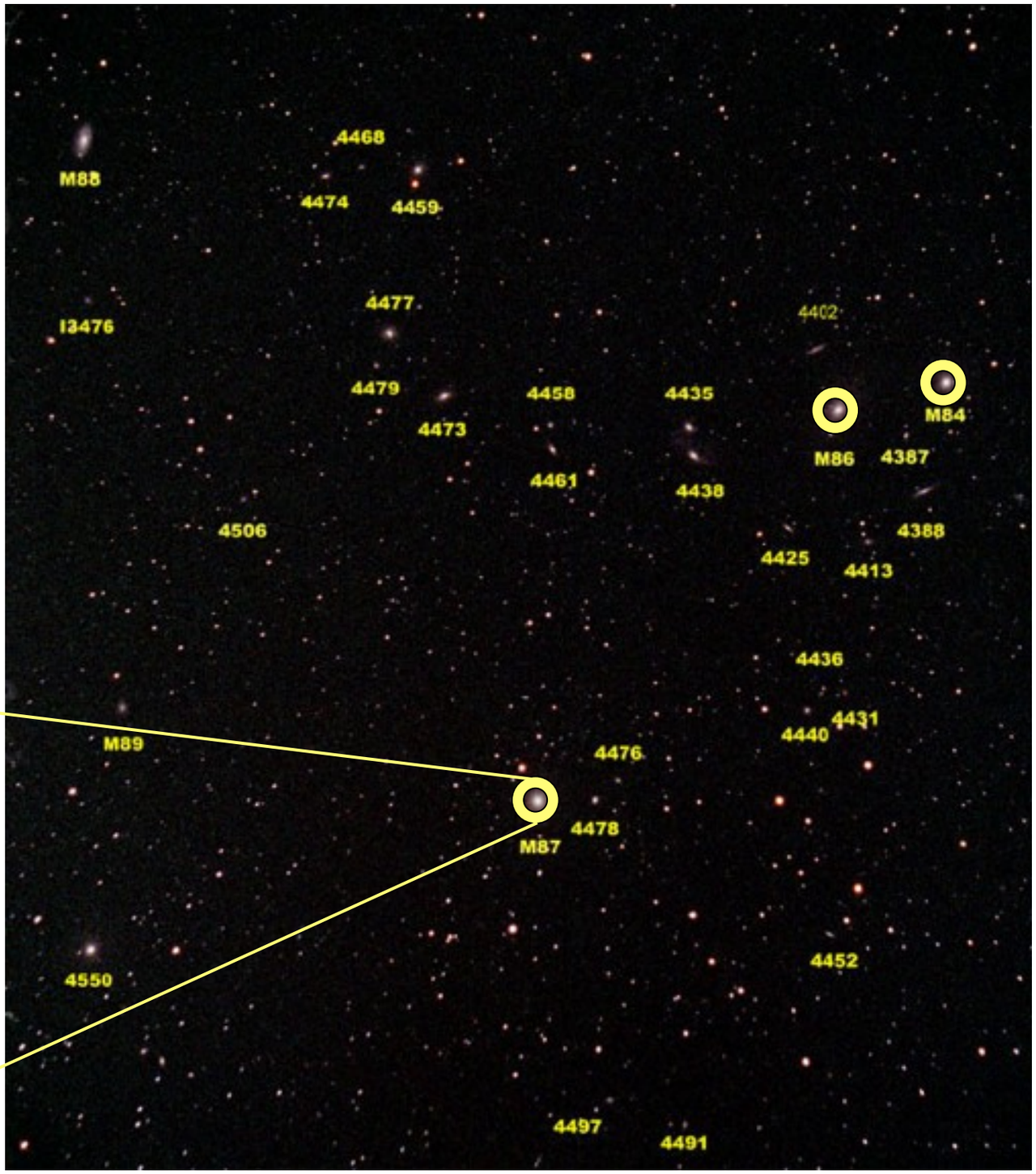
52 Mlyrs away from the Milky Way

About 13 Mlyrs across

Dominated by three giant elliptical galaxies

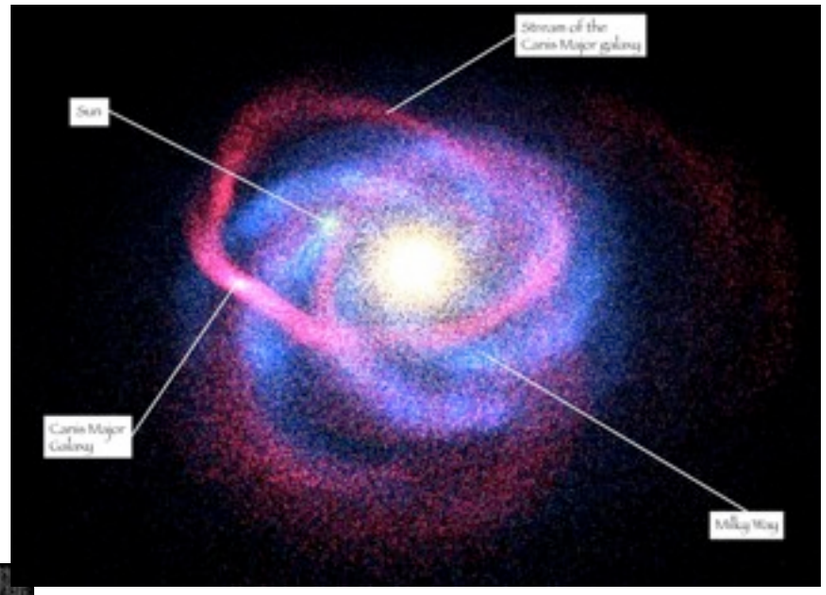
Our cluster is headed right for it.





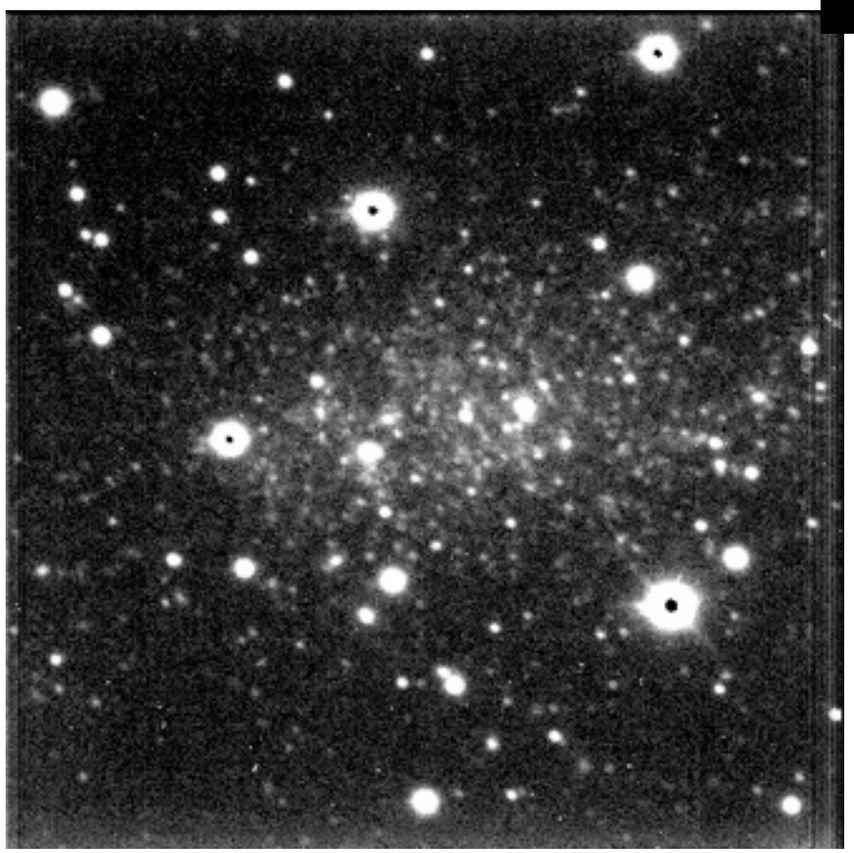
Is the Milky Way Alone?

We have lots of neighbor galaxies

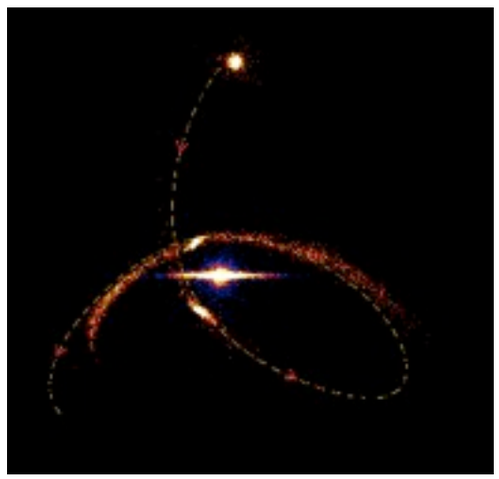


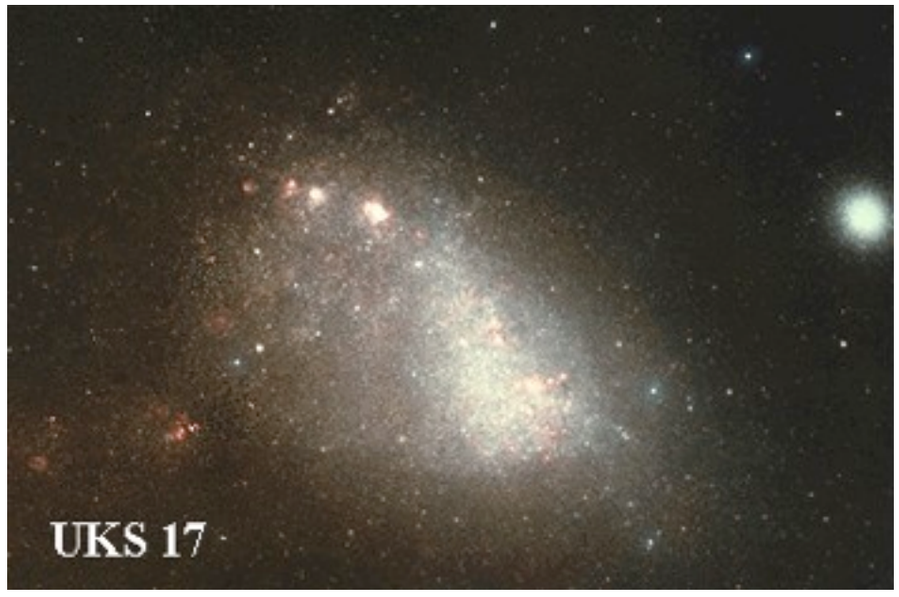
Canis Major
(42,000 ly away)

Large Magellanic Cloud
(180,000 ly away)



Sagittarius Dwarf Elliptical
(80,000 ly away)





Small Magellanic Cloud
(250,000 ly away)

The Local Group

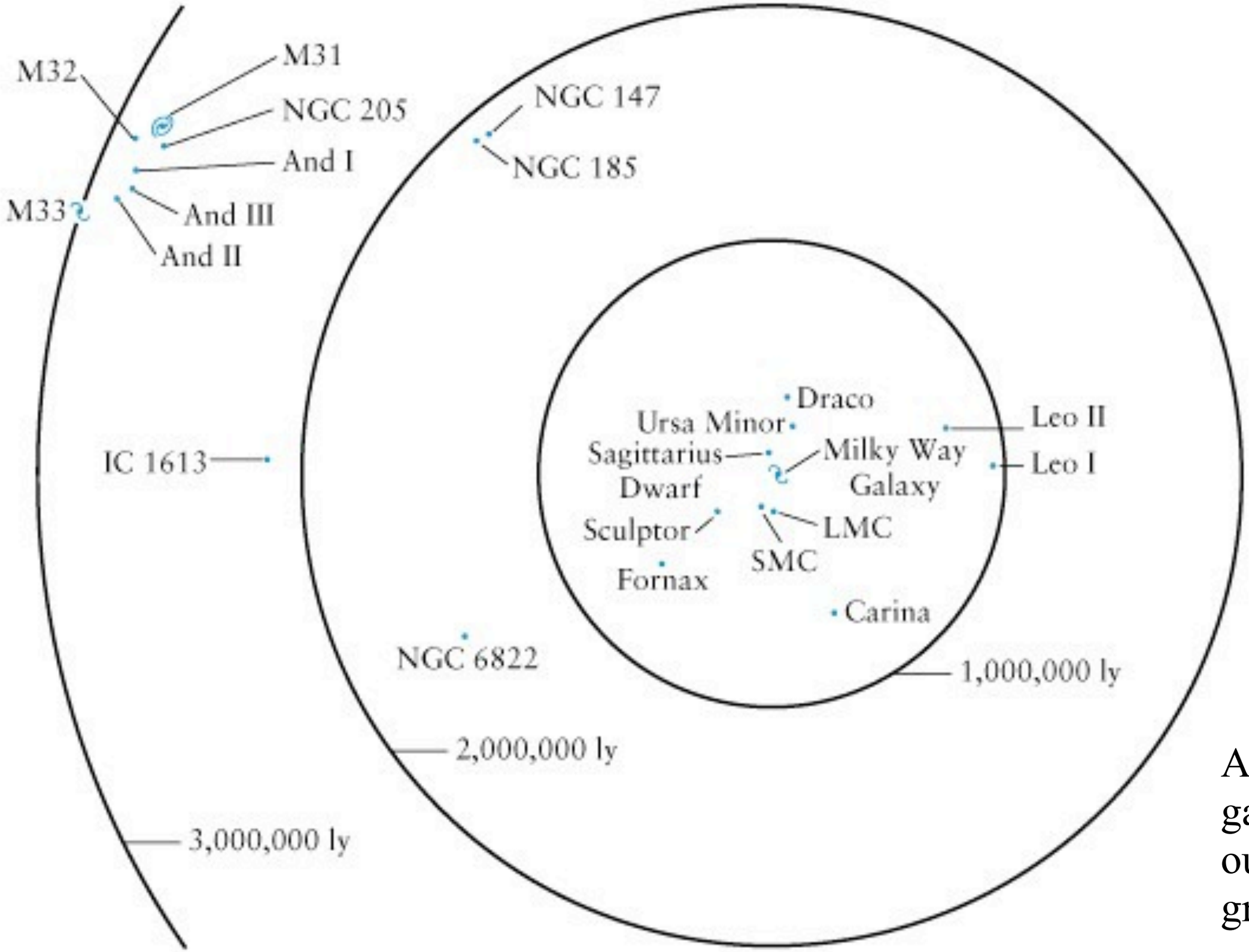
- Our Galaxy is in a "group"
  - a poor, irregular cluster
  - Called the Local Group
- Dominated by two large spirals
  - The Milky Way = us
  - The Andromeda Galaxy (M31)
- About 40 smaller galaxies
  - Some satellites of the big two
  - M33 (small spiral)
  - Lots of dwarfs ellipticals and irregulars

Andromeda (M31)

Triangulum (M33)

Local Group dwarf galaxies

The Local Group



About +40 galaxies in our local group

The Local Group: Many Galaxies in the Same Town

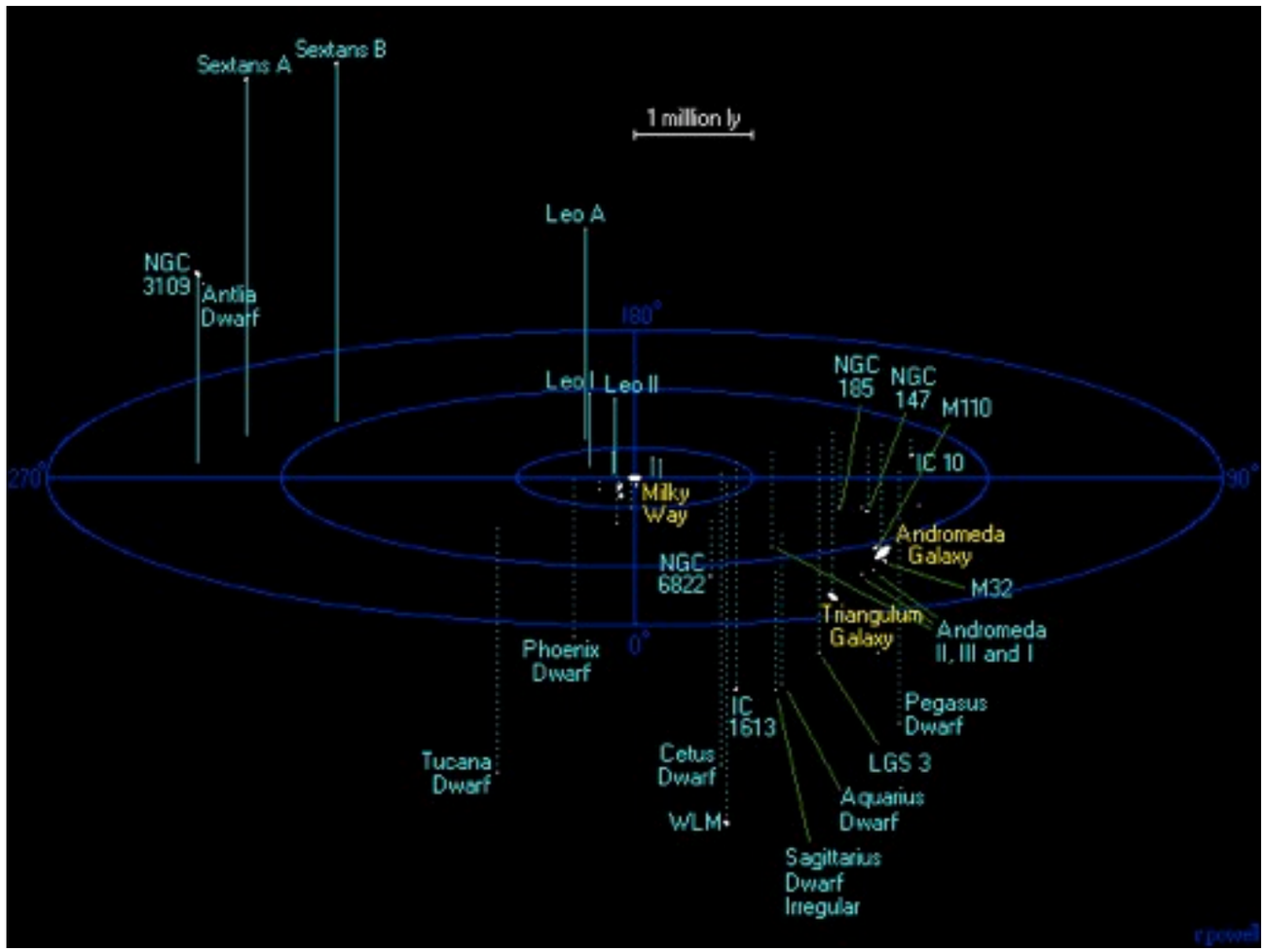
Milky Way

2.3 Mlyrs

Triangulum (M33)

Local Group Dwarf galaxies

Andromeda (M31)

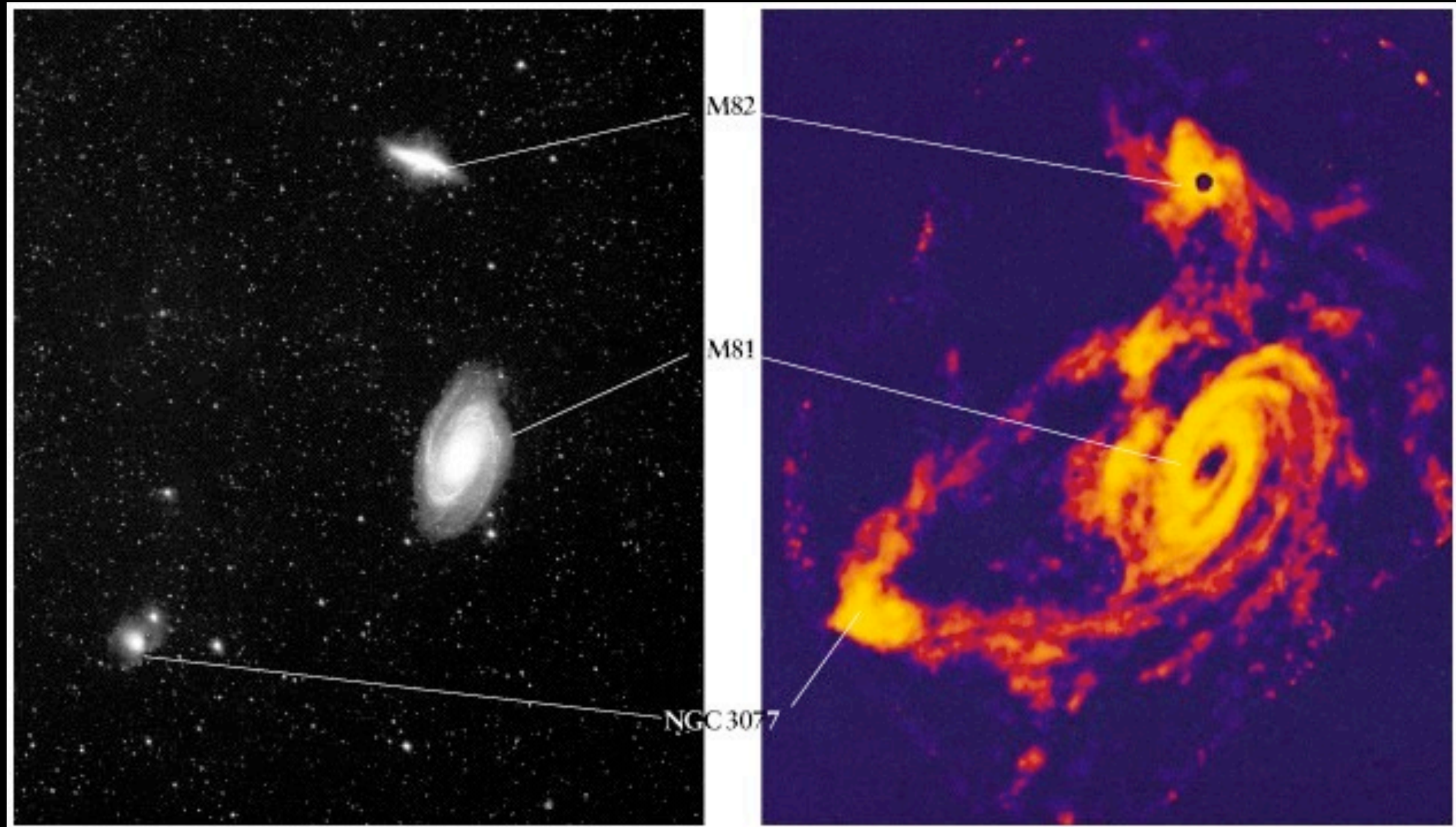


Galaxies evolve by <u>collision</u> and <u>merger</u>

Arp 148: The aftermath of a galactic encounter

NGC 6050: A collision between two spiral galaxies

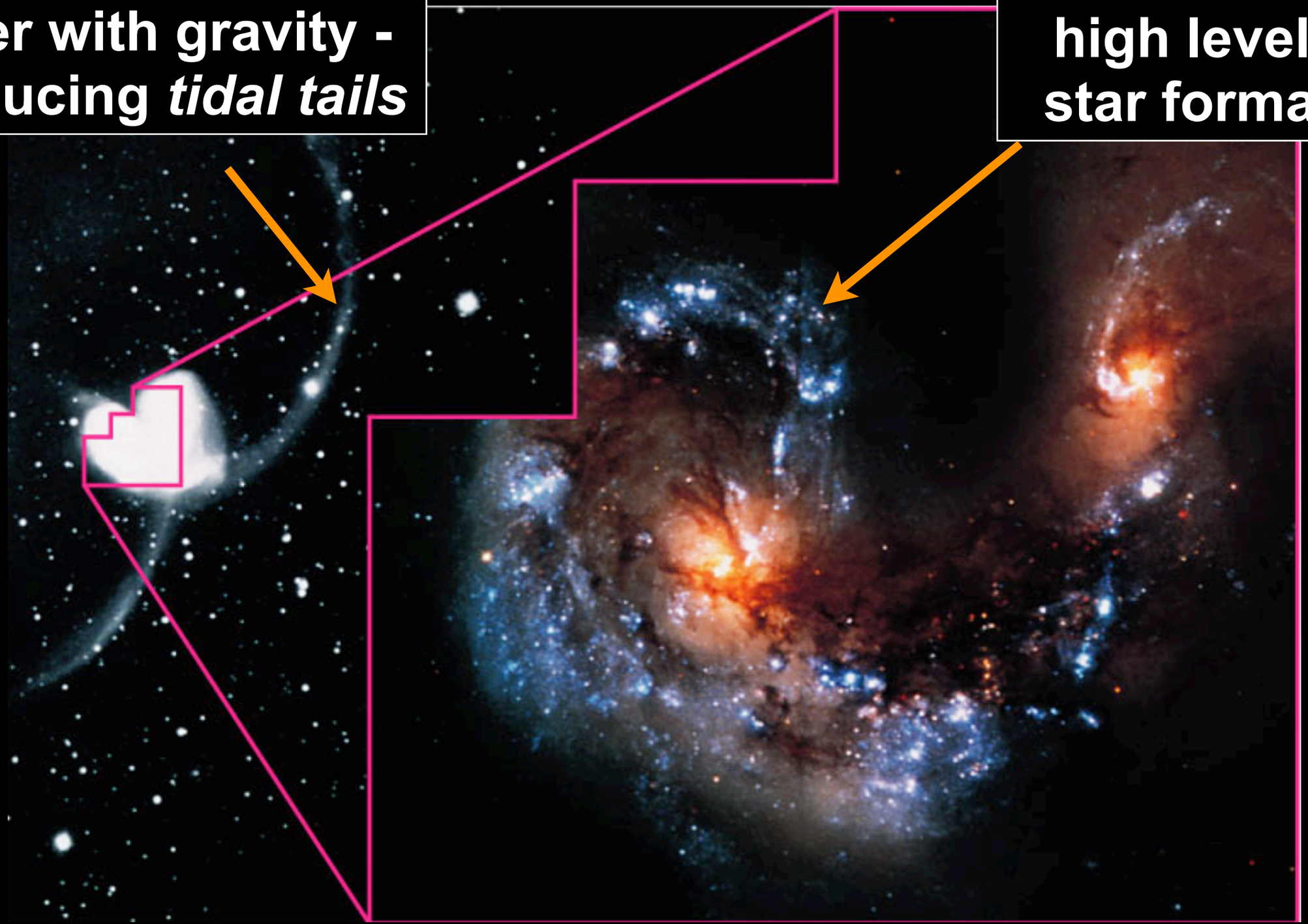
“Normal” galaxies show evidence of past interactions



What happens when galaxies collide?

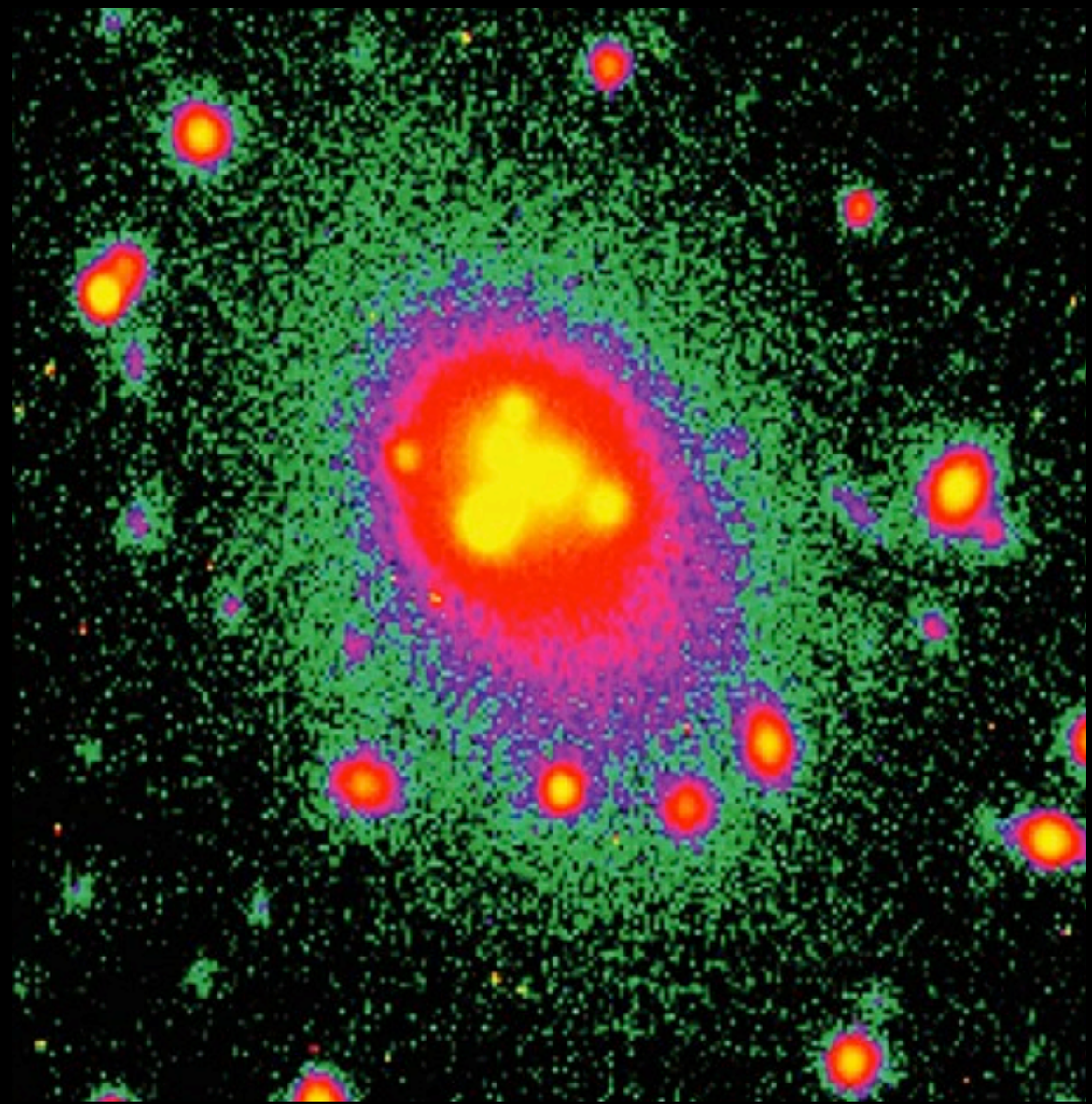
Can distort each other with gravity - producing *tidal tails*

Can trigger *starbursts* - high levels of star formation



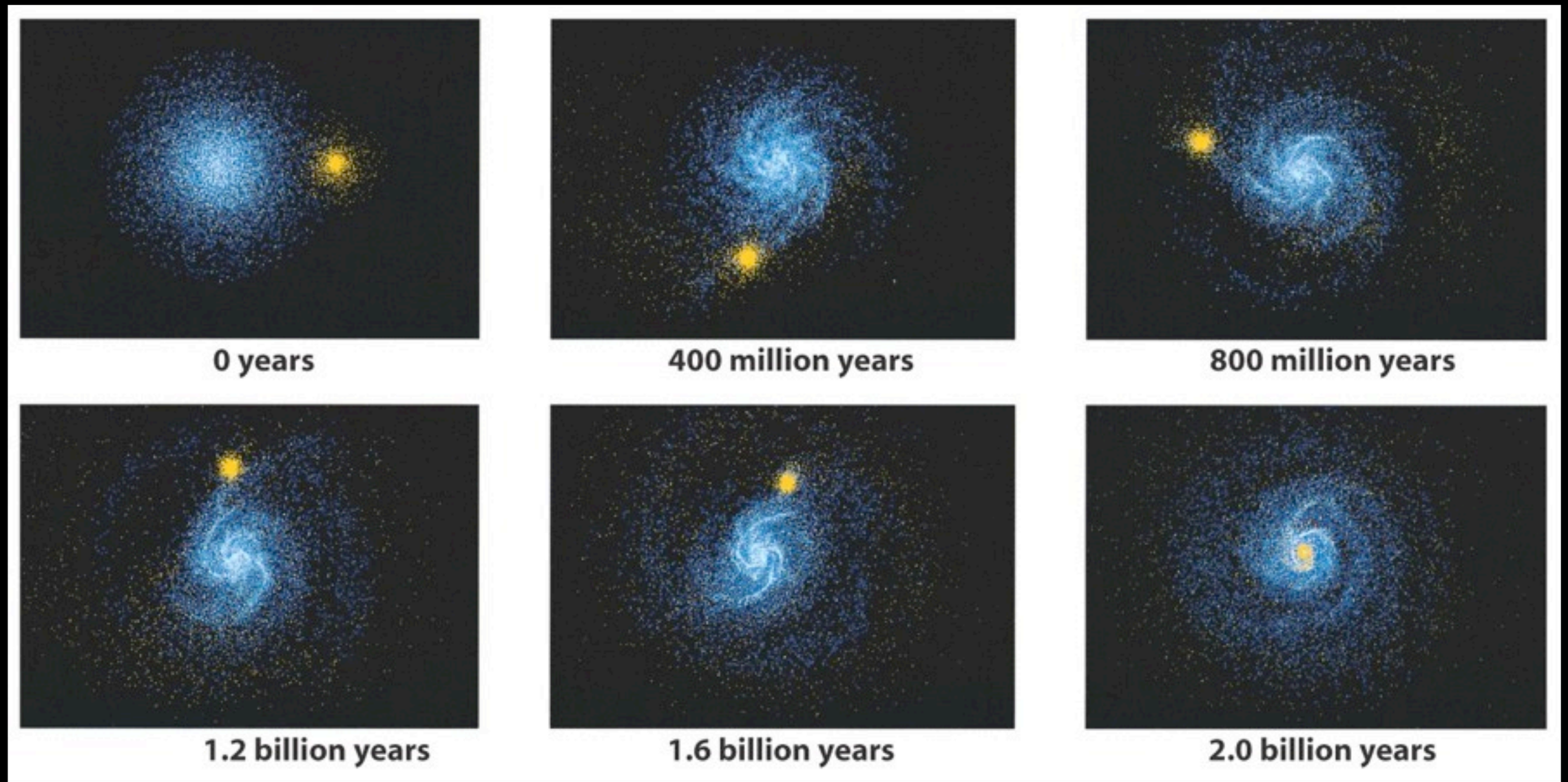
Giant Ellipticals: Evidence of galactic cannibalism

- Giant elliptical galaxies at the centers of clusters often have multiple nuclei
- Remains of smaller galaxies only partly disgested!
- Evidence they formed from multiple mergers



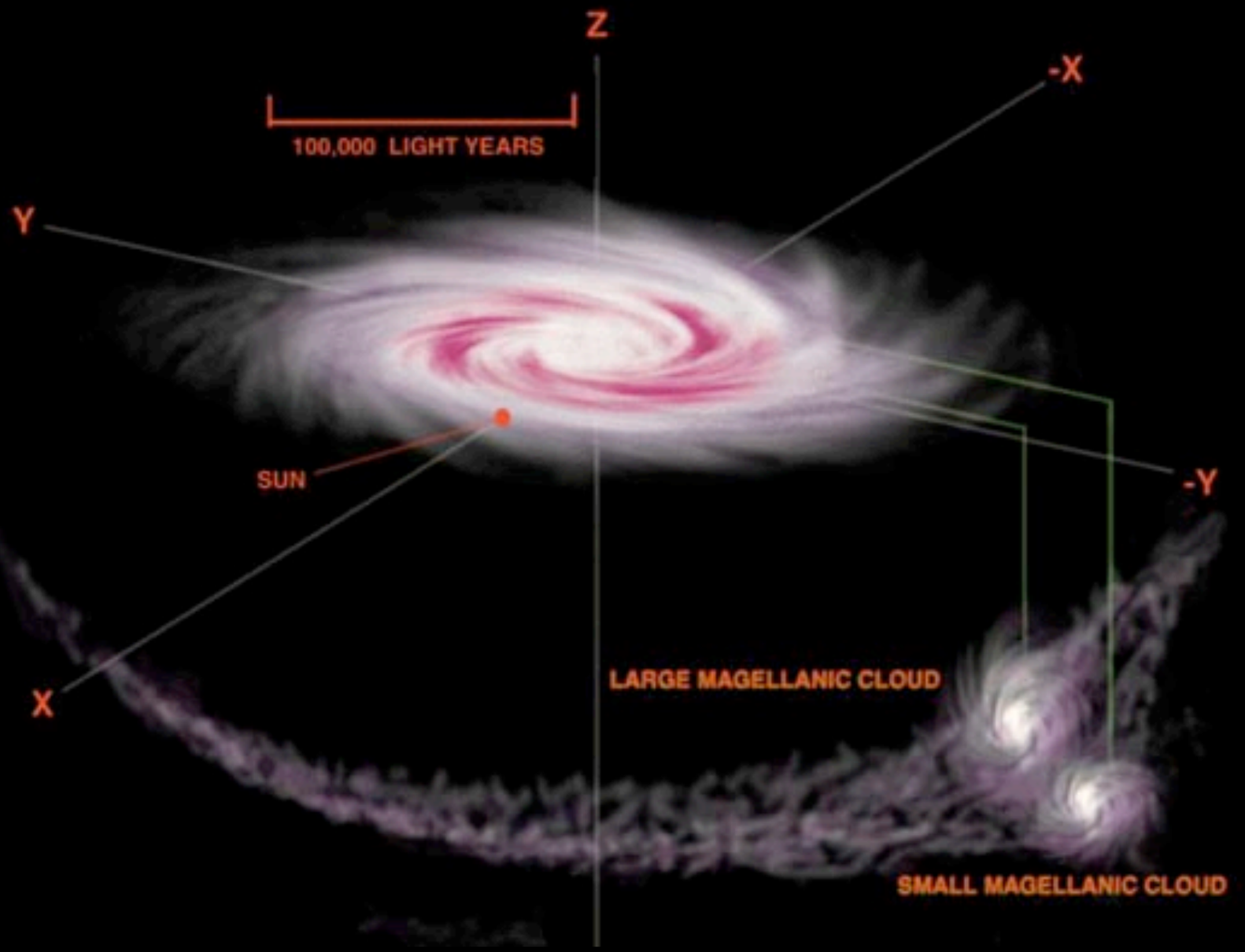
Central galaxy of cluster Abell 3827

Spirals seem not to have suffered recent major collisions



Mergers with small galaxies add to a spiral's bulge, but do not destroy its disk

Is our Galaxy undergoing galactic interactions?



As the Magellanic Clouds orbit the Galaxy, a stream of gas is stripped off by its gravity

The Andromeda Galaxy

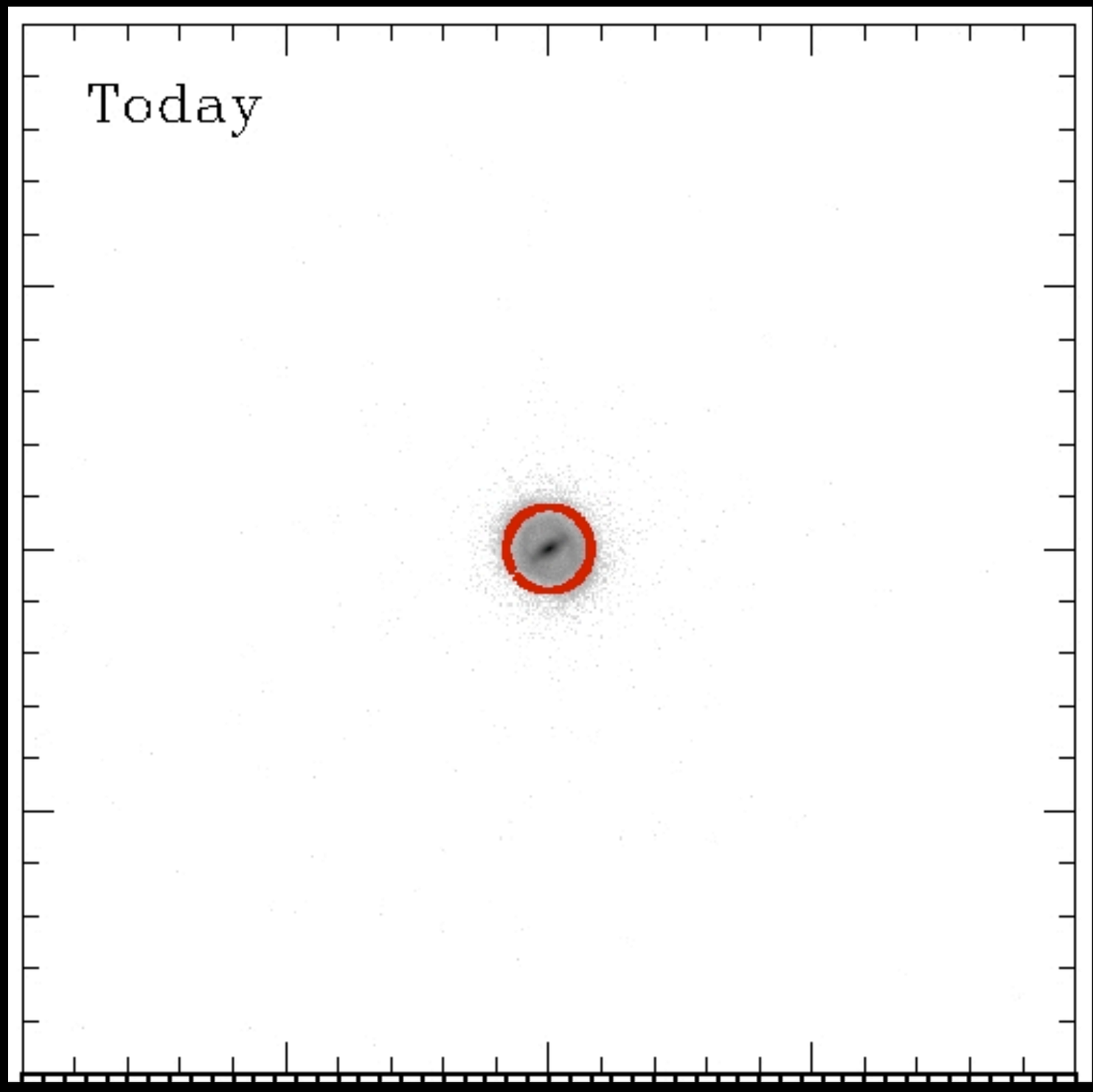
- 2.5 million light years away
- About the same size/mass as our Galaxy
- Also a spiral galaxy, like our own
- On a collision course with the Milky Way!

Milkomeda

The Milky Way and Andromeda begin to merge in about 2 billion years!

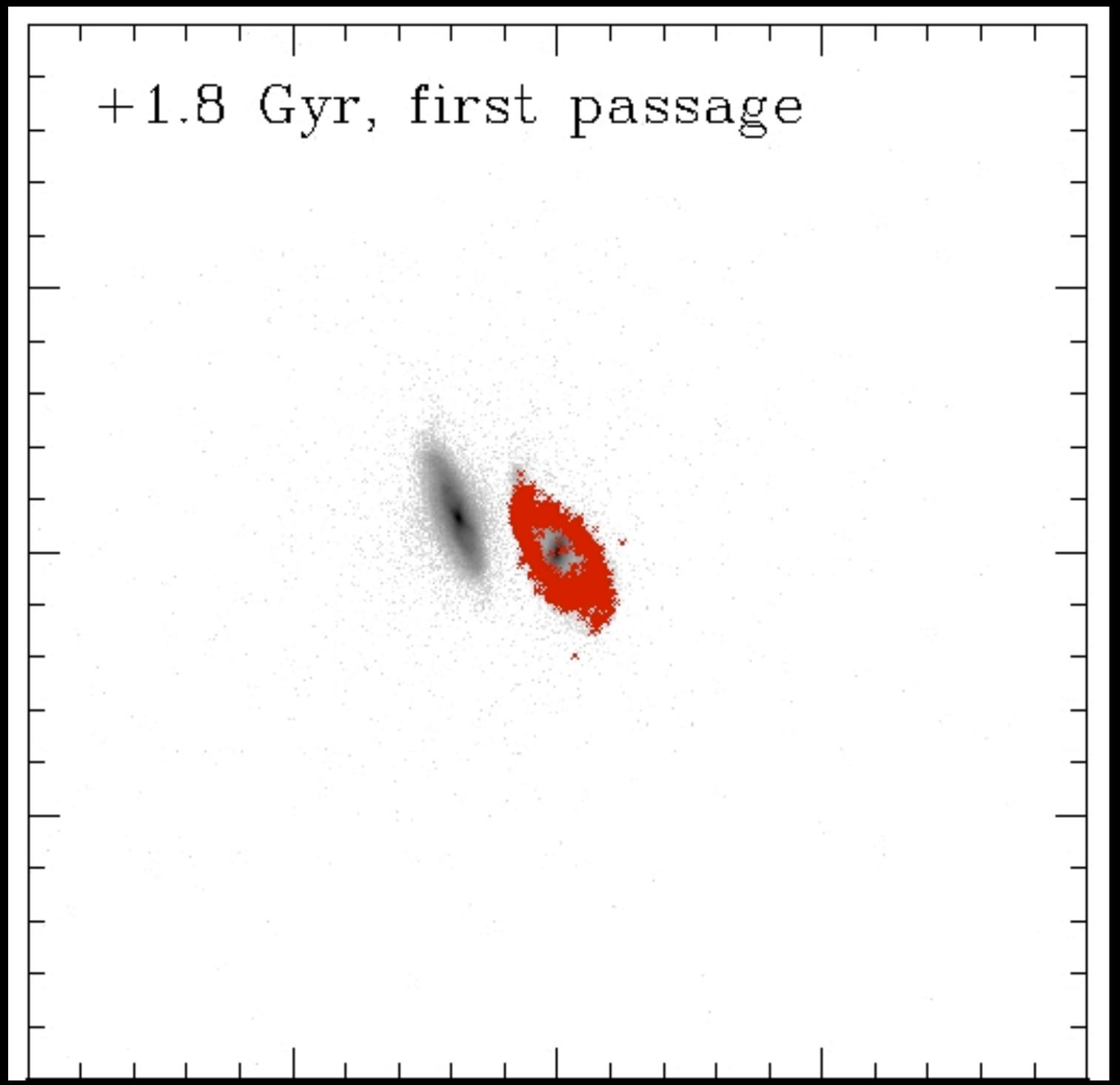
What is the fate of our solar system?

Simulation particles (stars) at the Sun's distance from galactic center in red



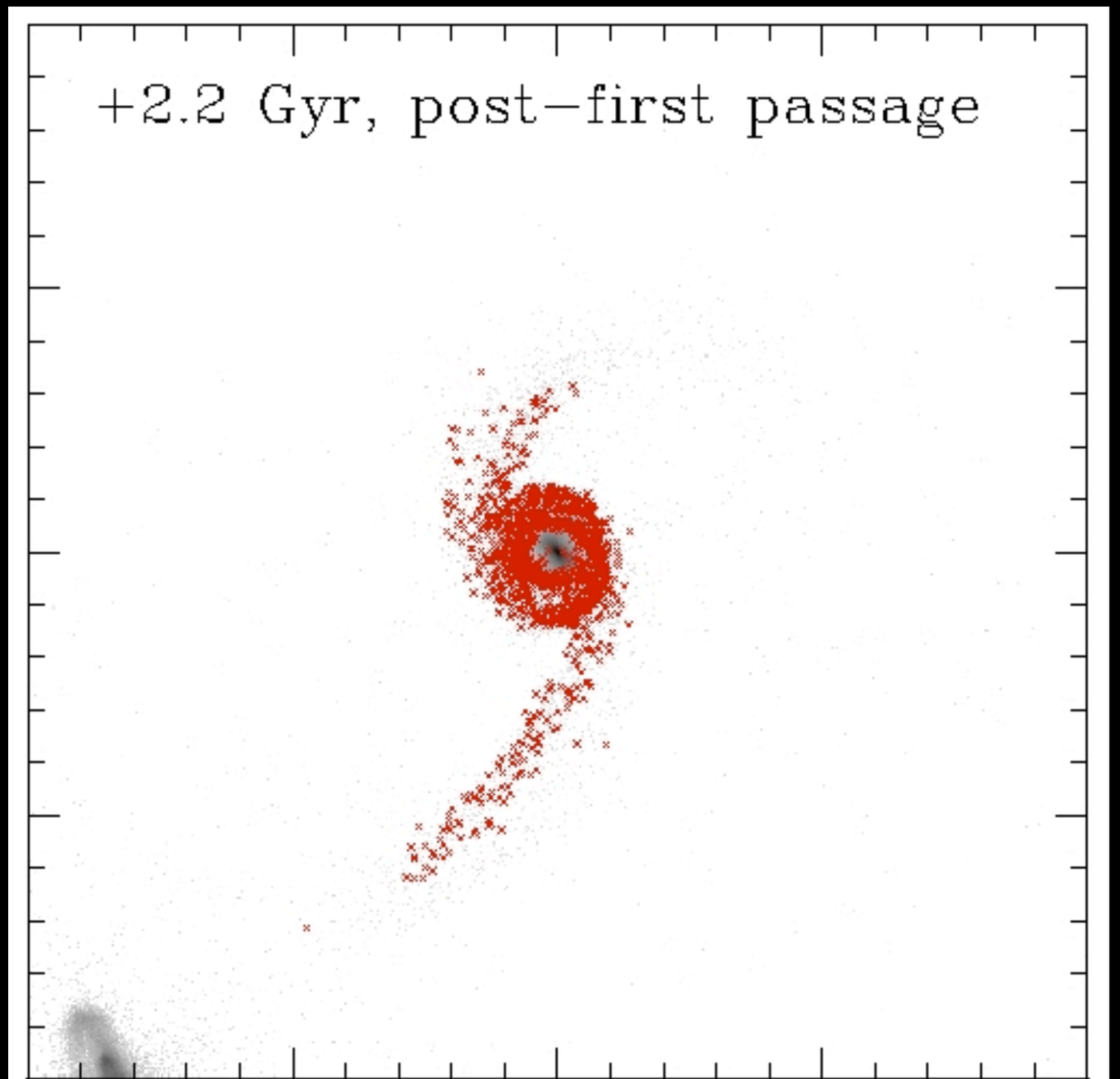
First Milky Way-Andromeda Encounter

Andromeda's gravity distorts the disk of the Milky Way.



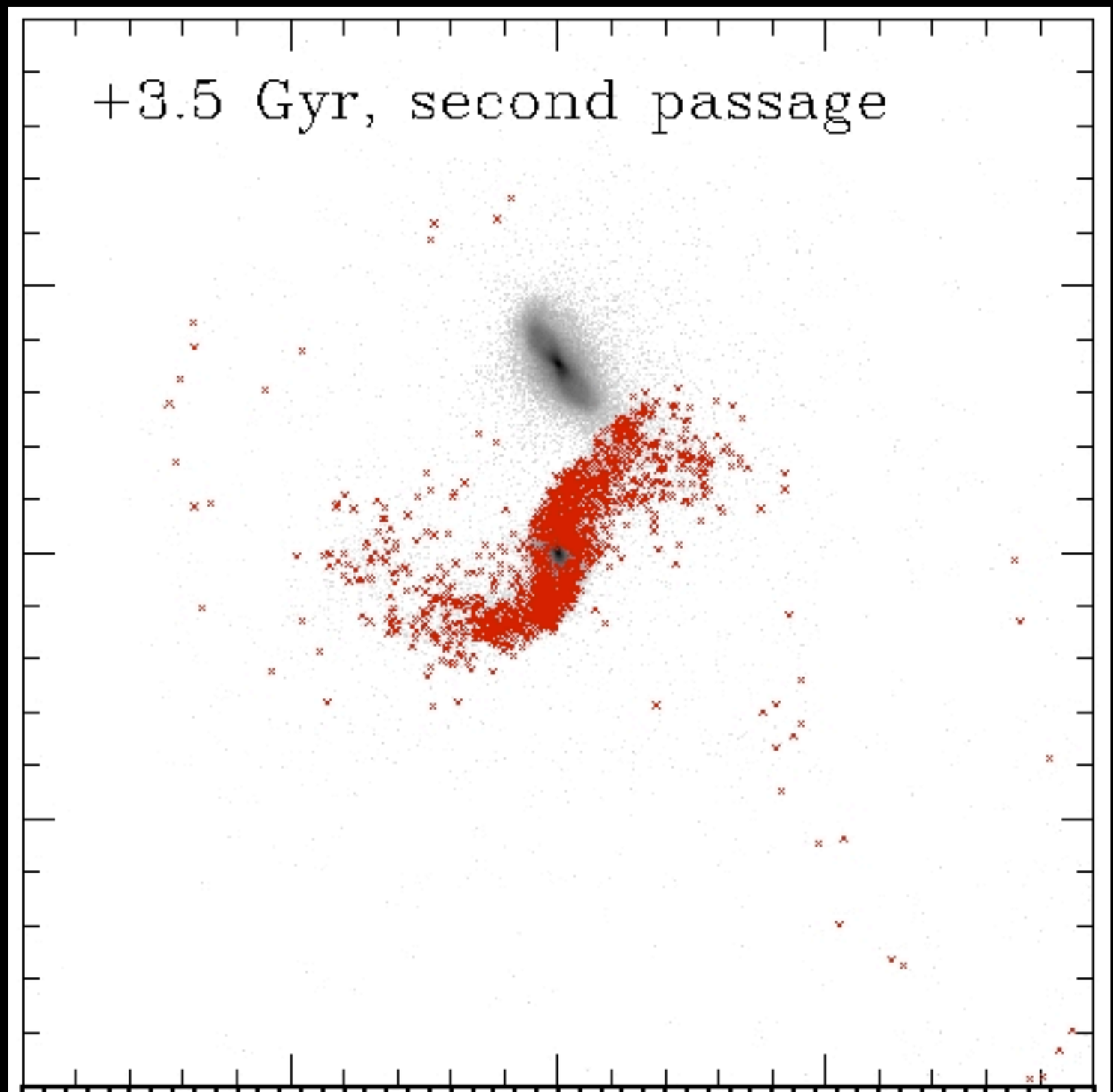
Sun ejected to galactic outskirts?

After first passage, there is a small chance that the Sun gets thrown out into the tidal tails, about 12%



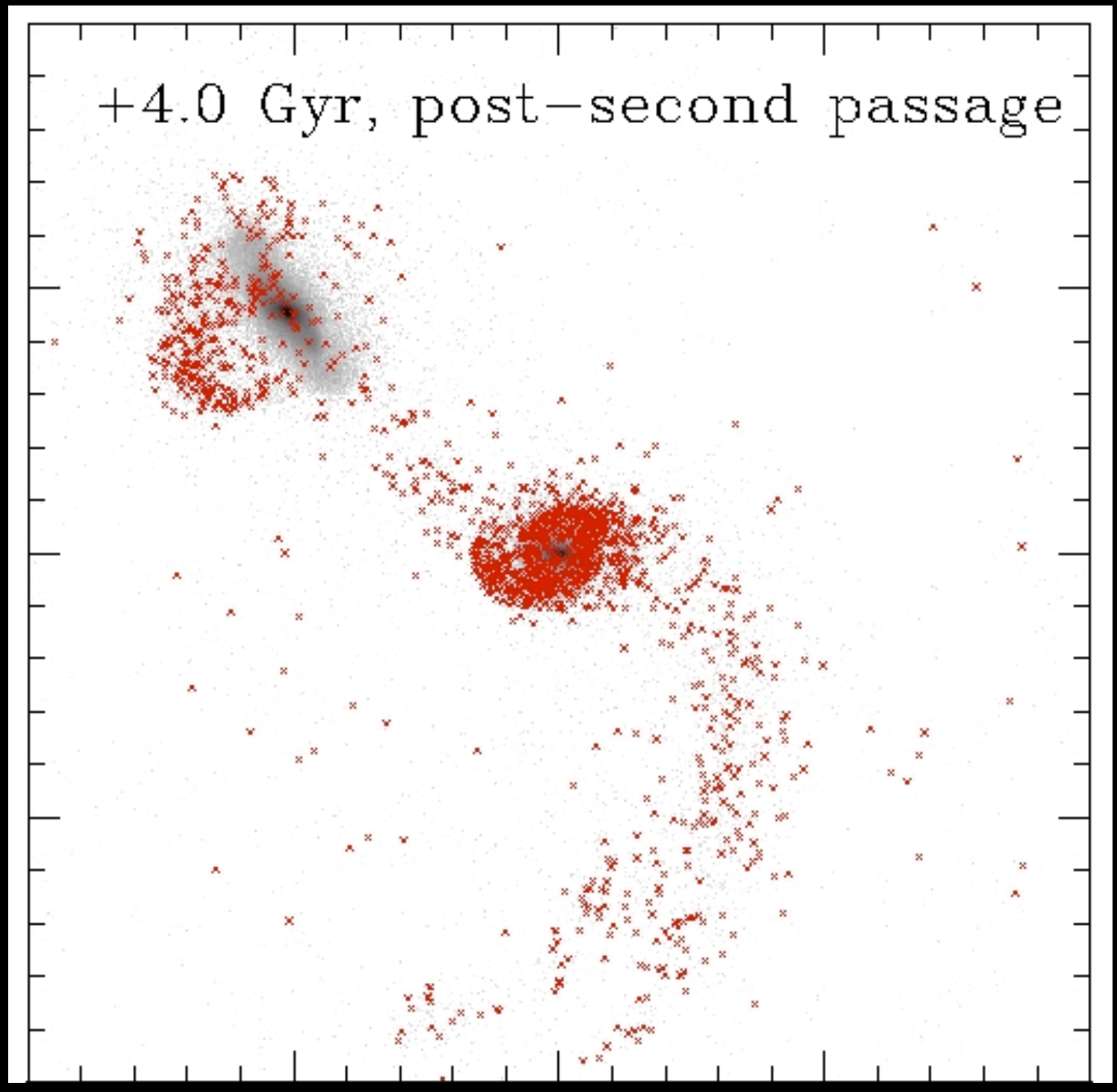
Second encounter

3.5 billion years from now, the Milky Way and Andromeda have their second close encounter on the way to merging



Sun switches sides?

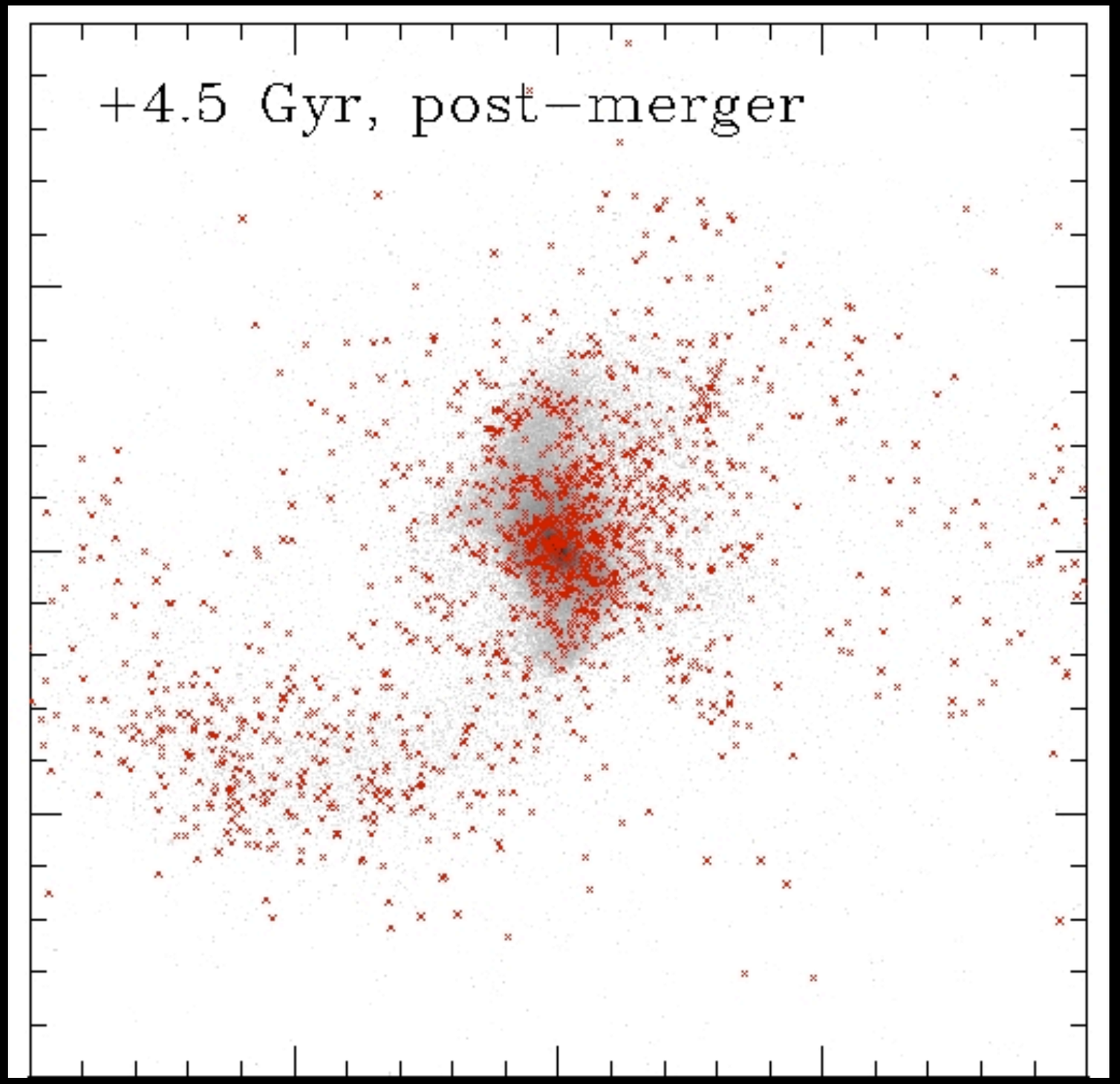
There is a <3% that Andromeda will "steal" the Sun from the Milky Way during the second encounter!



End result

Post-merger, there is a 68% chance the Sun ends up >65,000 light years from the merged galactic center.

Less than 1% chance of falling to the center.



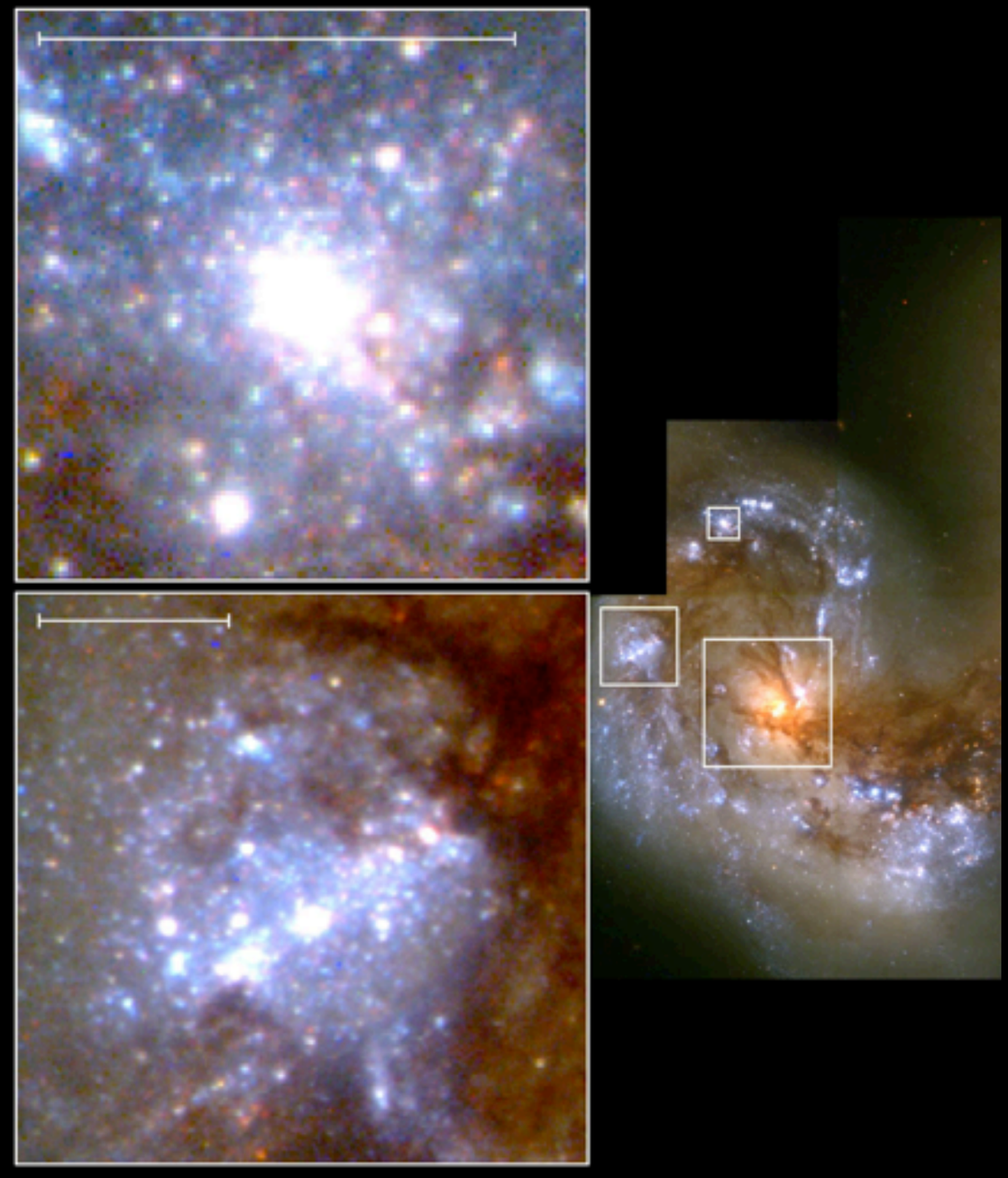
What are the risks to the solar system?

Star Collisions?

Even with ~1 trillion stars involved, the odds of a head-on stellar collision is extremely small

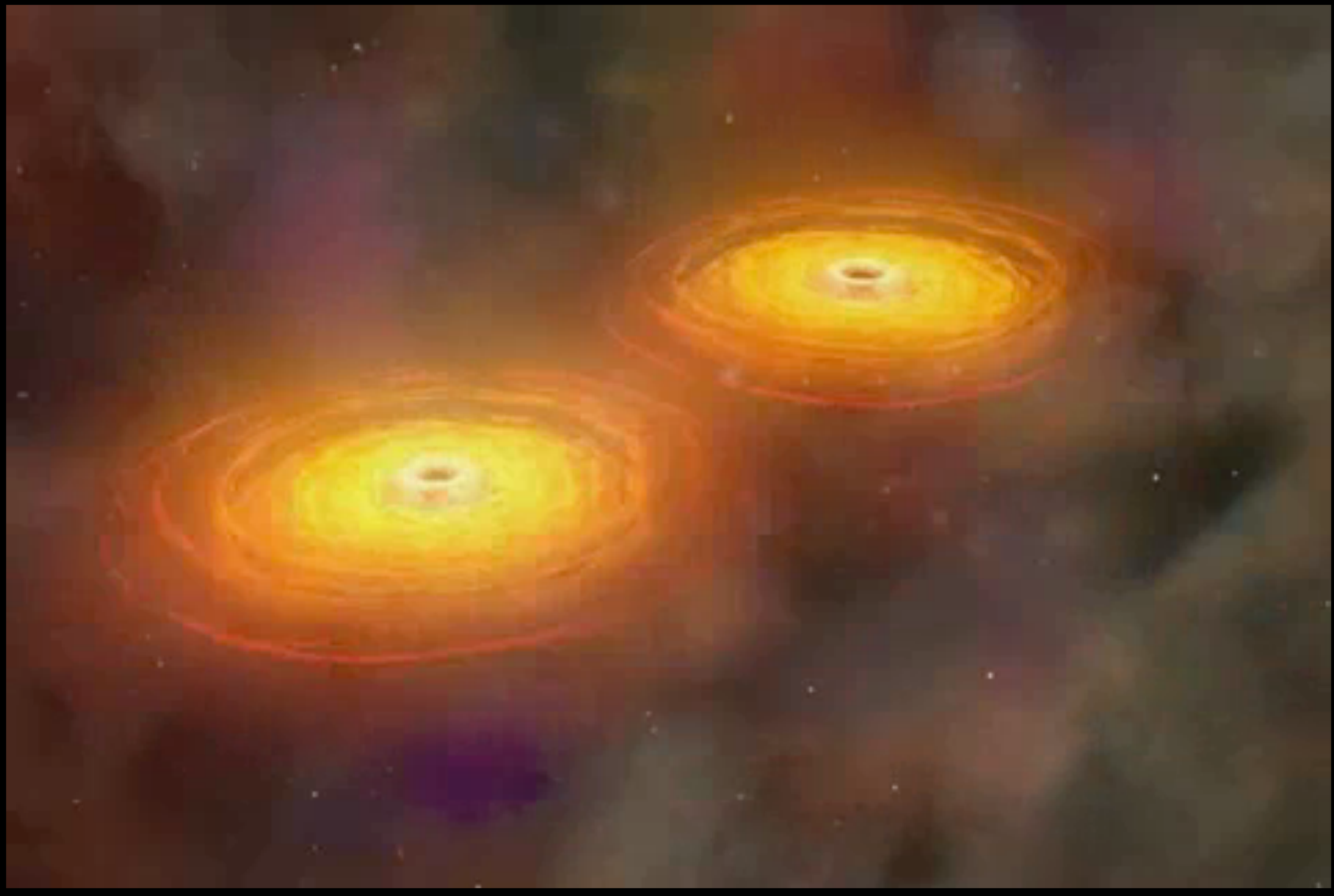
Risks to the solar system: Starburst encounters

- Collisions ignite huge bursts of star formation
- Starbursts produce lots of massive stars
- Raises supernova rate from ~2 per century to ~1 per year!
- Encounter with a starburst region: bad!
  - Hot massive stars emit lots of UV light
  - Increased chance of nearby supernova



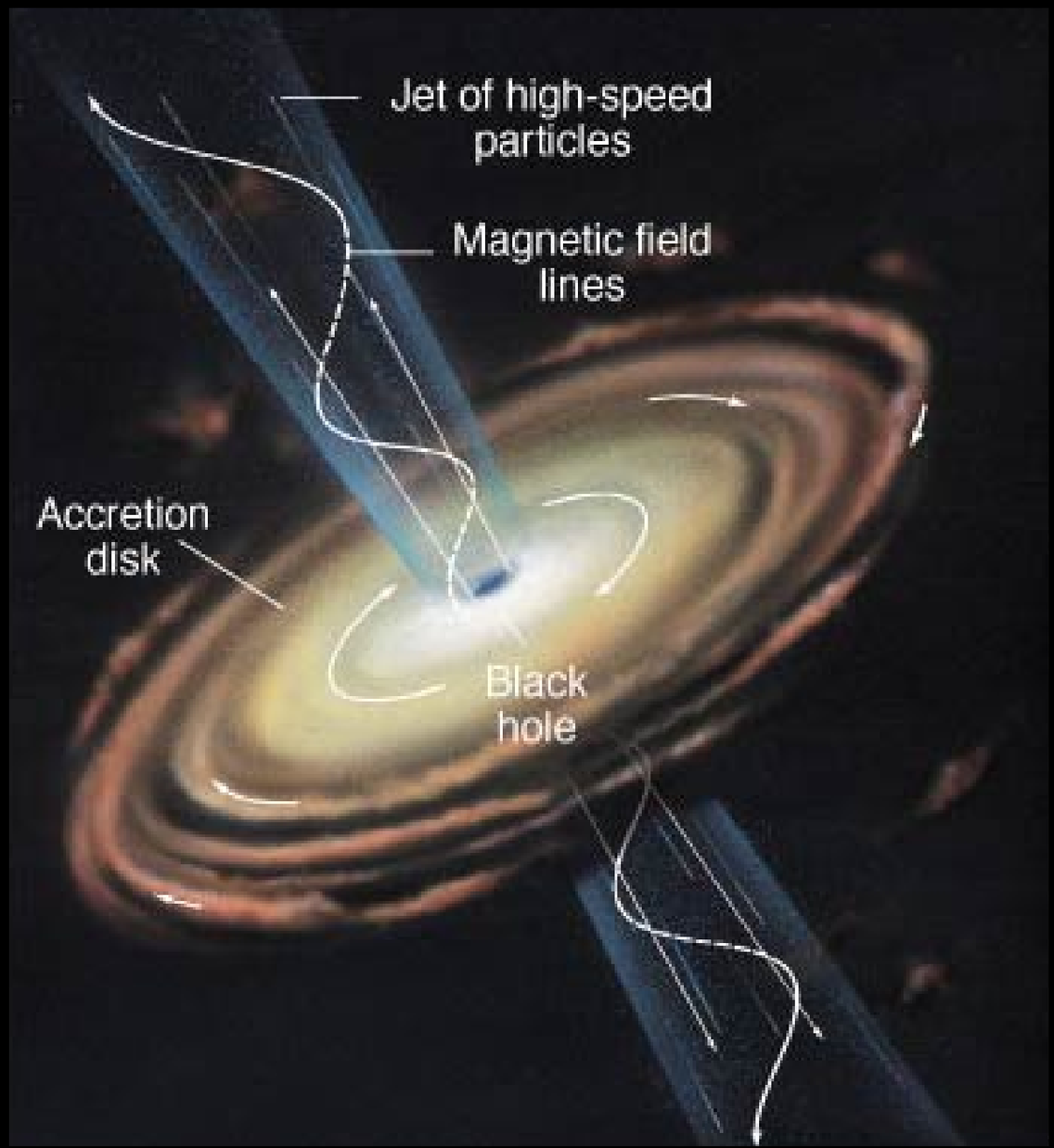
Starburst regions have many massive stars

Risks to the solar system: Supermassive black holes



Milkomeda could have an *active galactic nucleus*

- Material falling into the black hole forms an *accretion disk*
  - Friction in disk turns kinetic energy into thermal energy (heat)
    - Heat produces radiation (X-rays!)
- Would require only ~1% of Milkomeda's mass falling into the black hole



The inner structure of an active galactic nucleus

Mitigation

- None!
- Even if we explore the galaxy, any system will have the chance of falling into the center.
- But more colonies increases the chance of a long-lived human race.

Could Milkomeda look like this in 5+ billion years?

Imagine

- After getting flung 1 billion years into the future in a DeLorean, you notice that the sky is different.
- The sky is full of a galaxy, up close and personal.
- As you keep traveling into the future, you notice that it is changing position as it interacts with the Milky Way.
- You sigh in hope as you notice that the Earth and Sun are fine.
- Actually, the sky is prettier than before. This ain’t so bad!

Imagine

- But, in a few million years you realize that the Solar System has been knocked out of its usual Galactic orbit.
- And the Solar System is headed straight for the center of the Galaxy….. And there are many dangers there..
- As you die from lethal amounts of UV radiation, you wonder why Brian didn't mention the beauty of the event.

The Biggest Threat?

Galaxies are enormous

And yet can still threaten tiny creatures like us

What about something bigger still?

Imagine

- After getting flung a few billion years into the future by Brian's spinning phone booth, everything seems normal.
- Humans must have moved the Earth.
- But something isn't right.
- Suddenly, the stars disappear from view.
- Then the outer planets, one by one: Pluto, then Neptune, and so on until Mars winks out of sight along with the Sun an inner planets
- Then the Moon is gone
- Next the Earth begins to rip in two!
- And finally so do you!
- As your body's atoms get ripped apart, you wonder why Brian didn't mention how painful it would be, and wish you had filled out your ICES form.

Top 10 Ways Astronomy Can Kill you or your Descendants

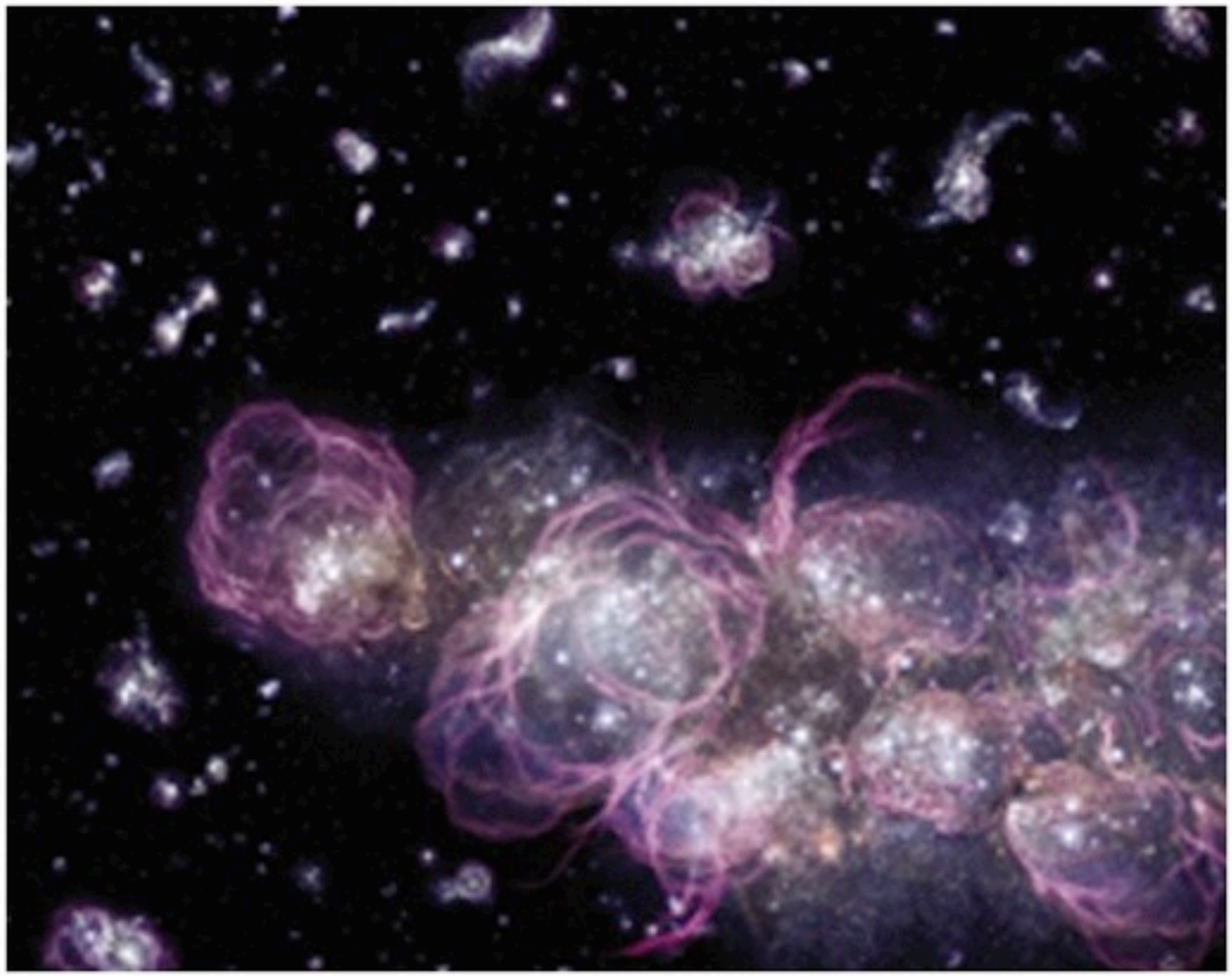
9. The End of Everything - Dark Energy and the Fate of the Universe

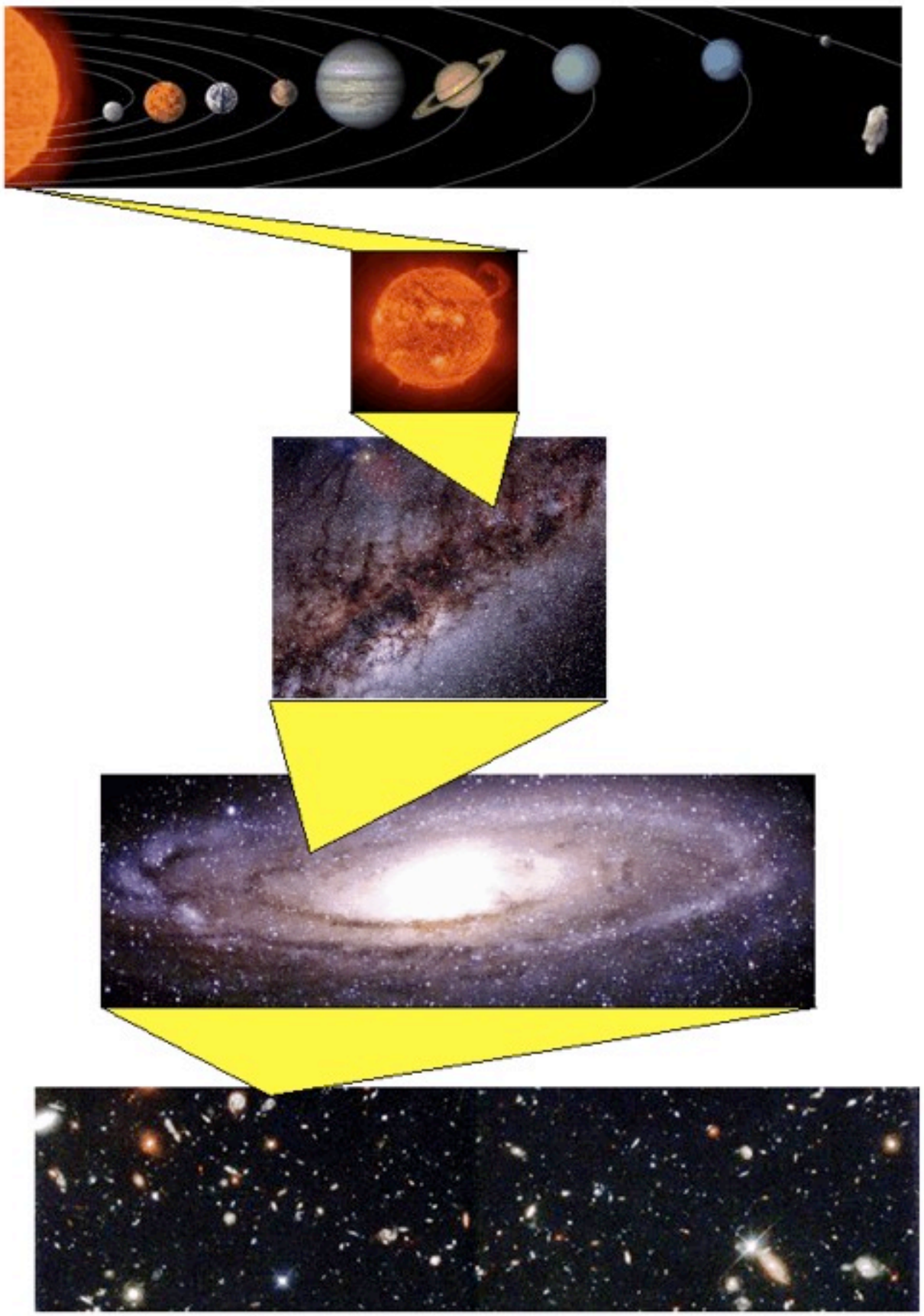
Cosmology

What is the Universe?

- All the matter, energy, space, and time we can ever detect

Cosmology is the study of the origin, structure, and evolution of the Universe





Astronomy: The Big Picture

Arguably, the biggest fish of all: Cosmology

- What is the Universe made of?
- How big is it?
- How old is it?
- How did it form?
- What will happen to it?