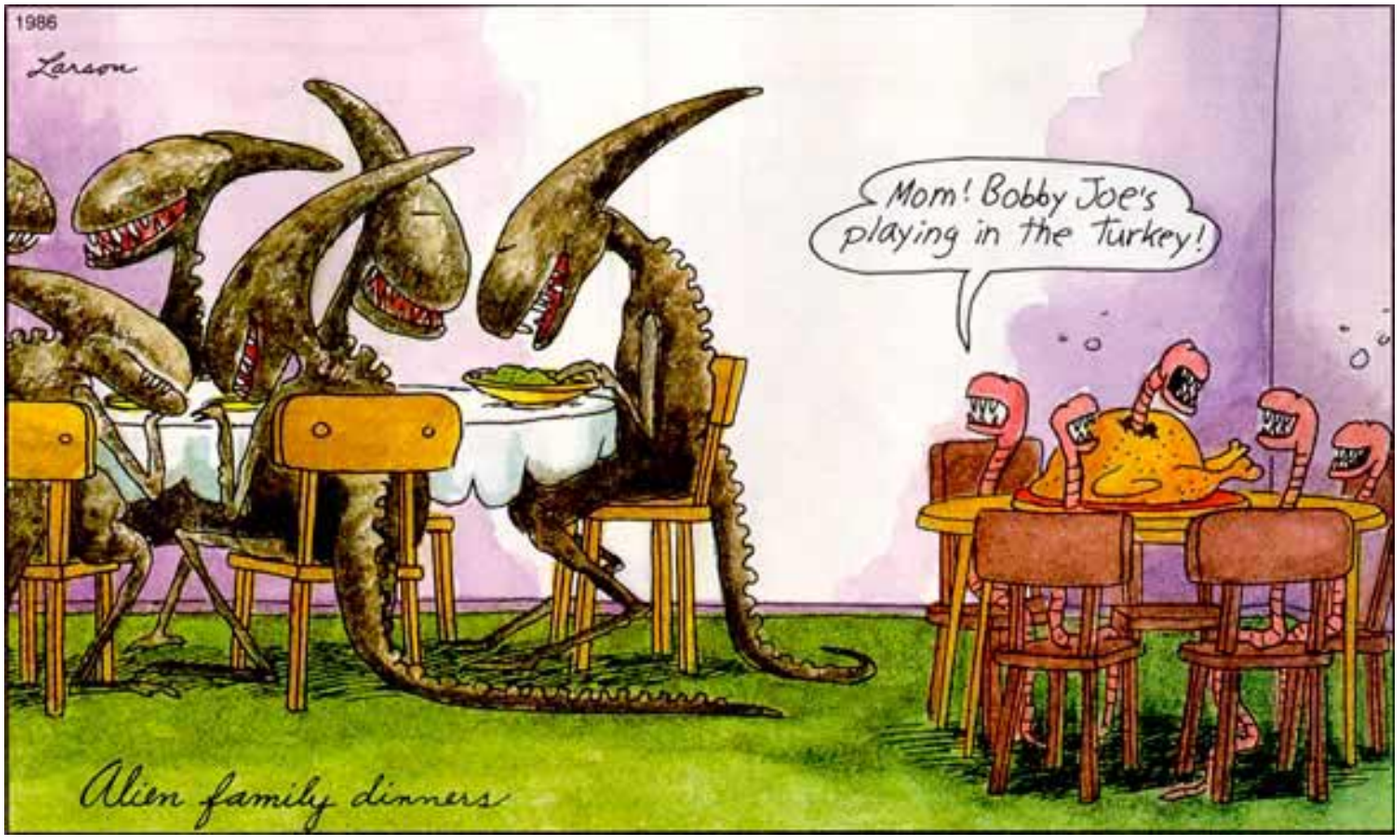
Killer Skies



- **HW 10/Moon Report** due Dec 2nd
- Solar Obs due now

- Last time: Galaxies
- Today: Galaxies Collide

Music: *The Universe Song* – Animaniacs

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!

Currently, Andromeda is about 2.5 million light years away
24 million trillion km away
The Andromeda galaxy is on a collision course– 300 km/s.
In about 2 billion years, it starts.

Milkomeda

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

Spiral structure of Milky Way and Andromeda will be destroyed

Incoming

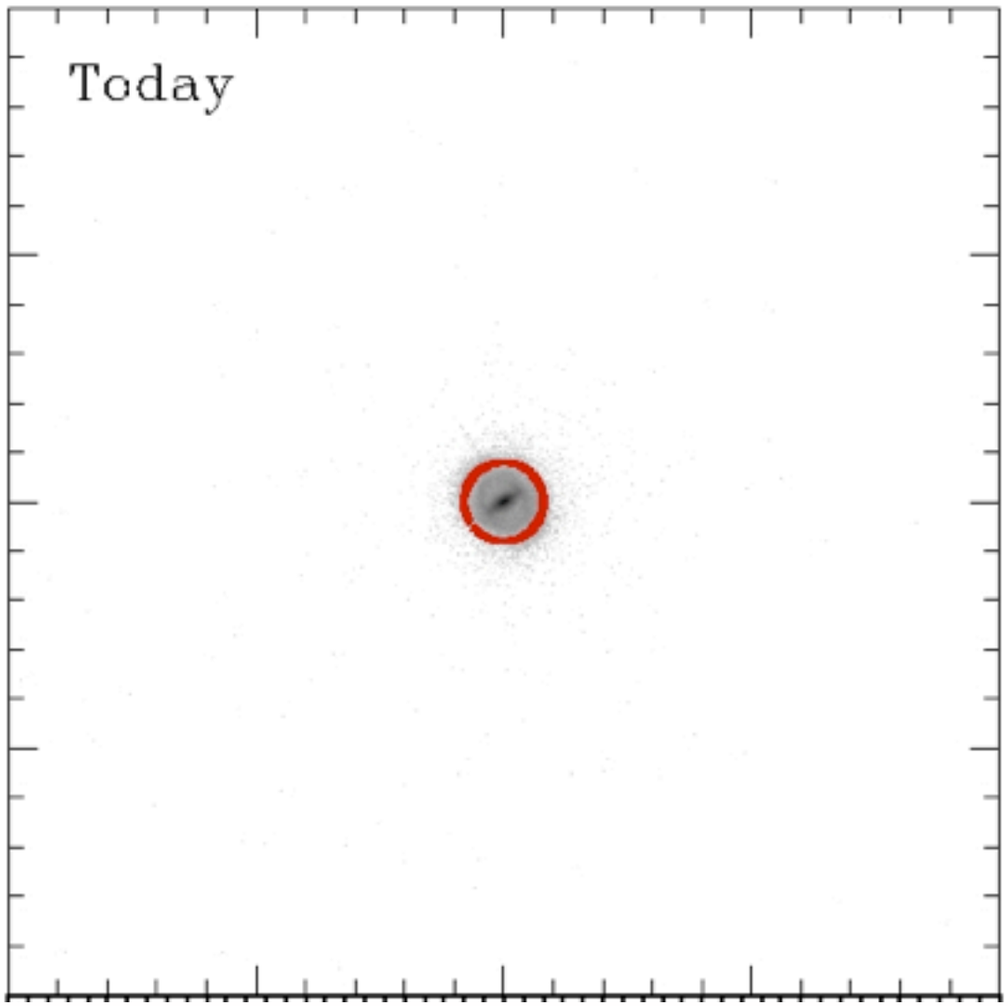
Spiral Metamorphosis

"This leaves us with the rather discomforting conclusion that most of the inner parts of the Galaxy, including the Sun, might not be saved from M31 after all, and the possibility of a merger in another four billion years cannot be ruled out."

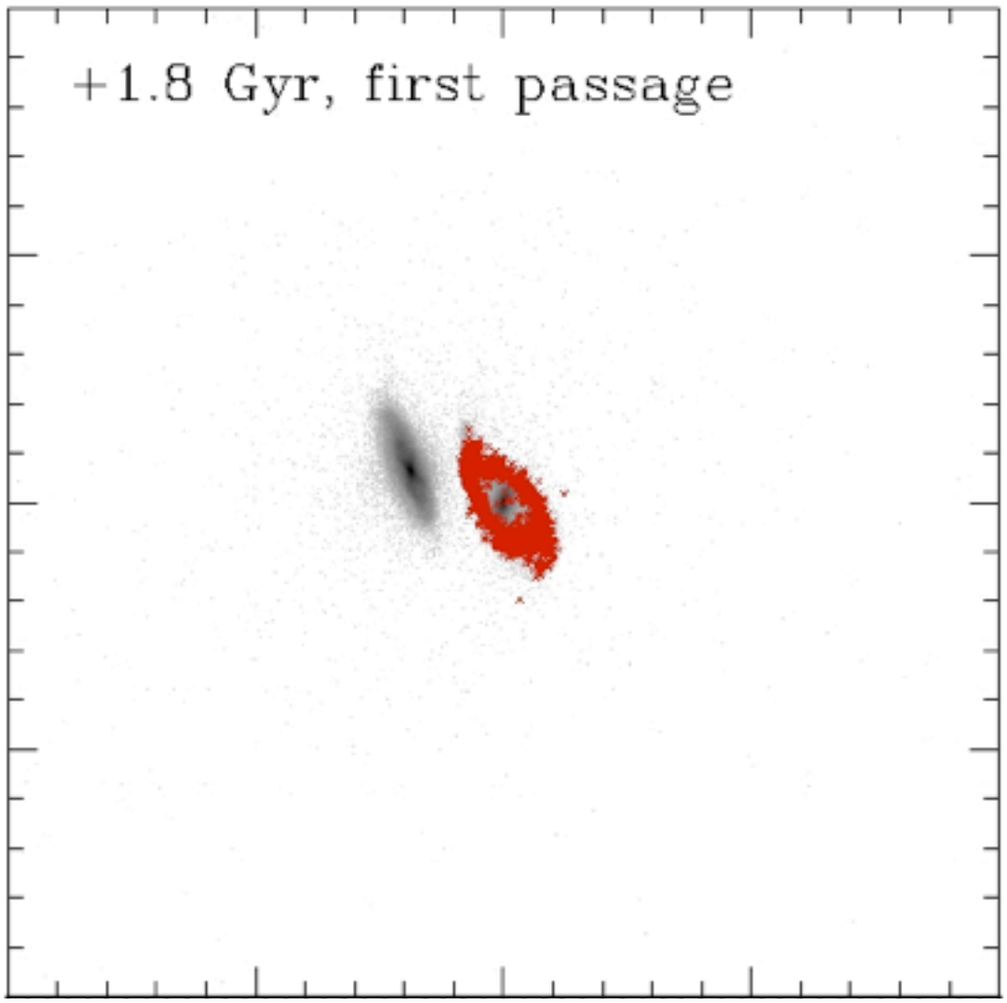
- Raychaudhury and Lynden-Bell, *MNRAS* 1989

Simulation of what that may look like
Assuming we have not died and can deal with the increased brightness of the Sun as it ages
First close encounter is in about 2 billion years
Takes another 3 billion years for the merger to be complete

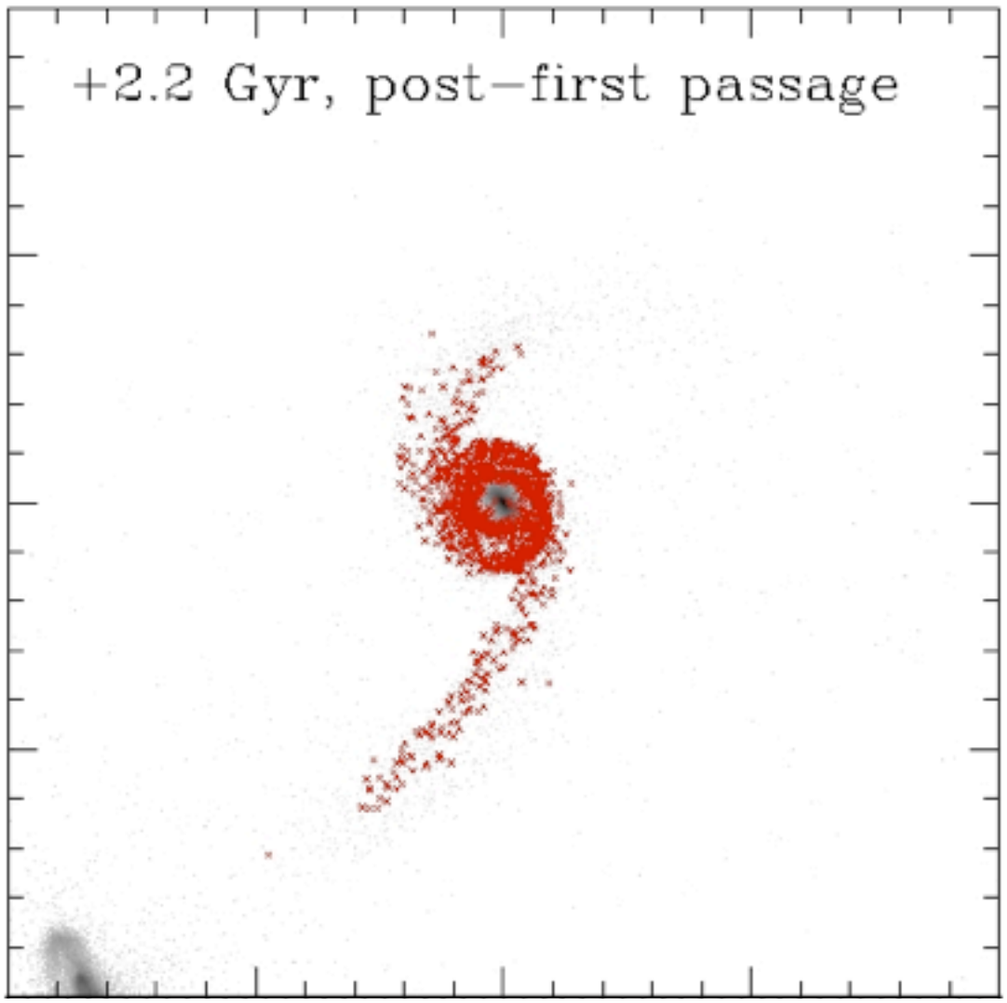
What is the fate of our solar system?



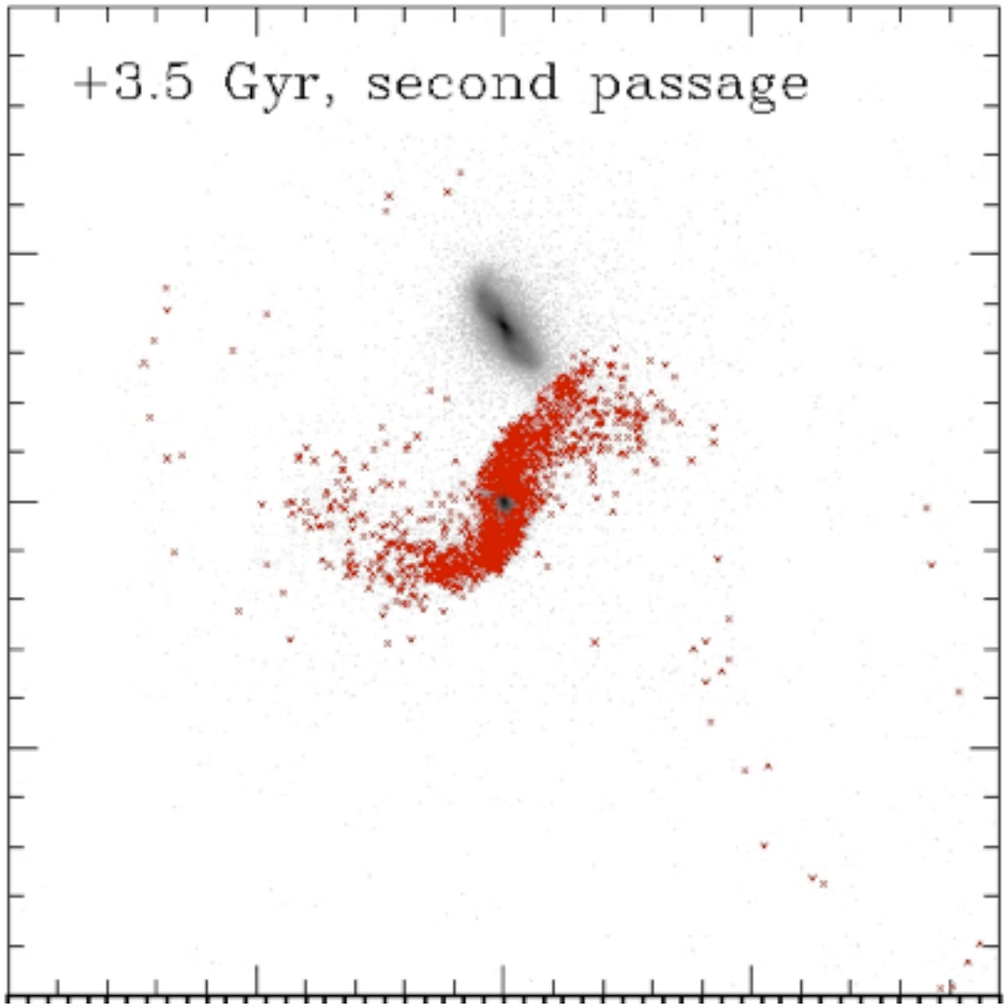
First Milky Way-Andromeda Encounter



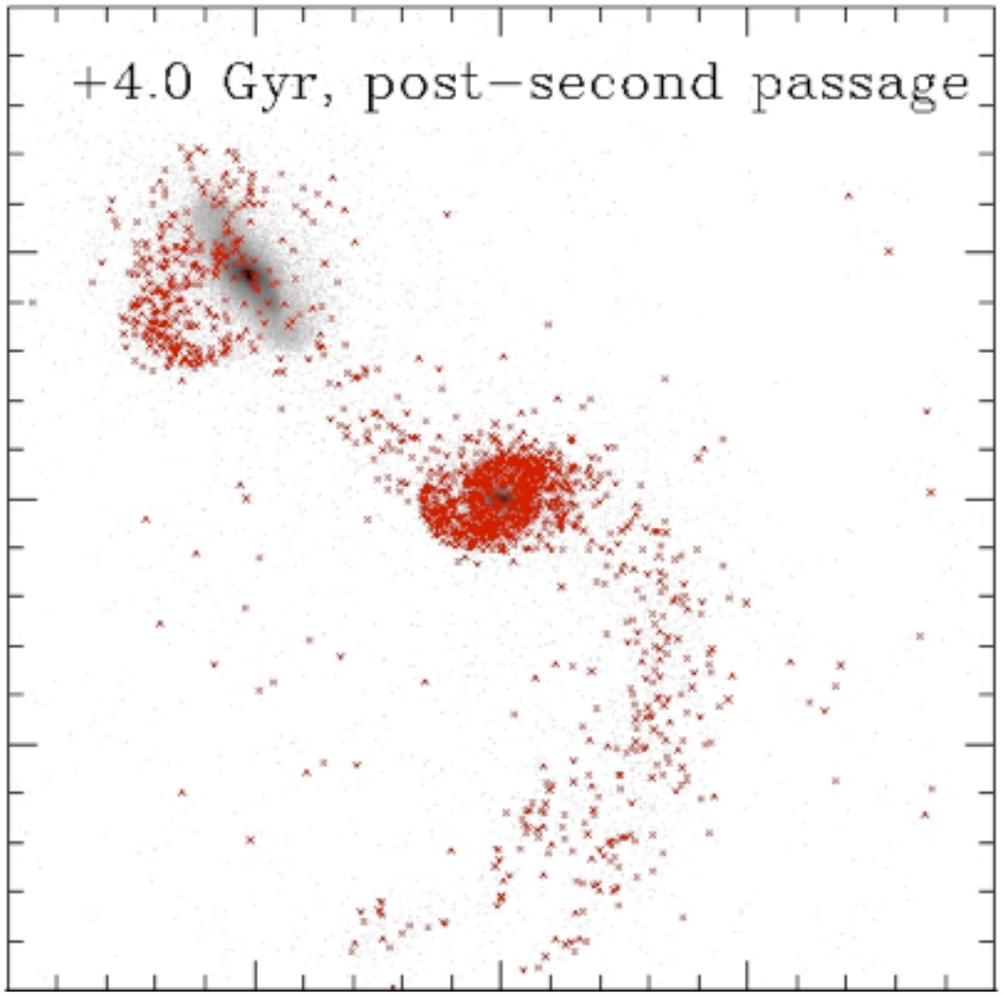
Sun ejected to galactic outskirts?



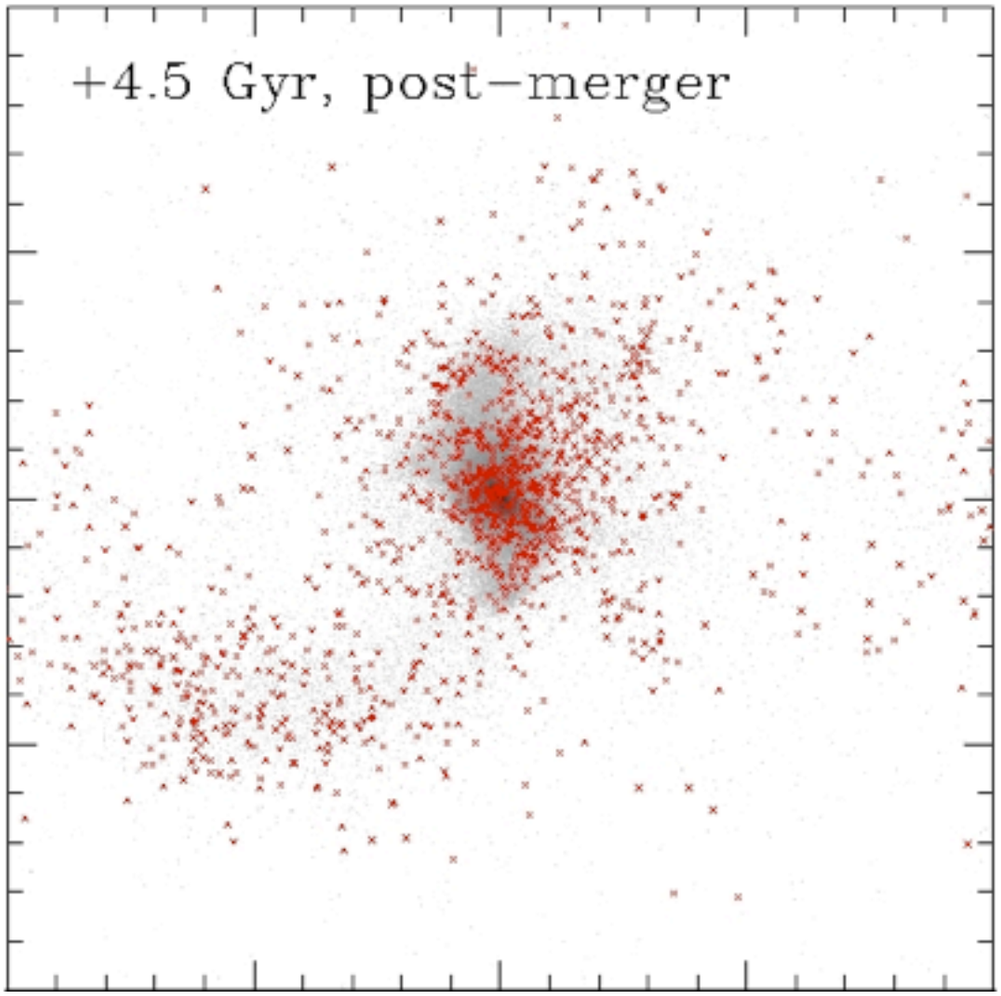
Second encounter



Sun switches sides?



End result



The Sun's orbit could be highly elliptical, so it could plunge into the center and then back out to the Galactic outskirts

Future Sky

Future Sky

What are the risks to the solar system?

Question

In about 2 billion years the Andromeda galaxy and the Milky Way galaxy will collide, should we worry about the Earth being splattered by a star?

A.Yes

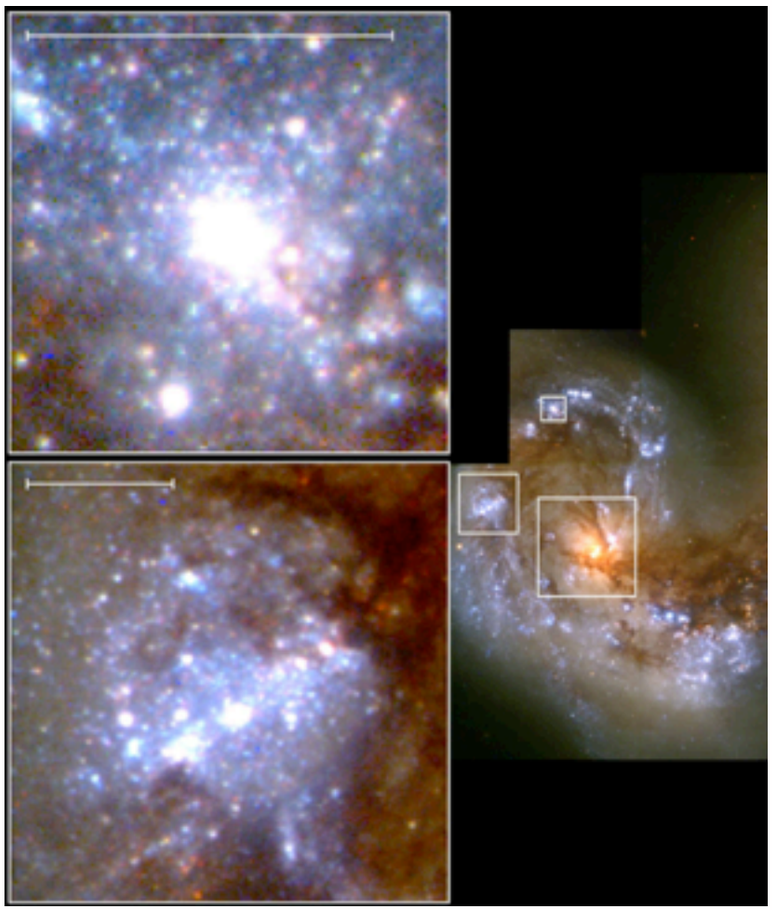
B.No

No! Very very tiny chance of two stars colliding in the process.

Star Collisions?

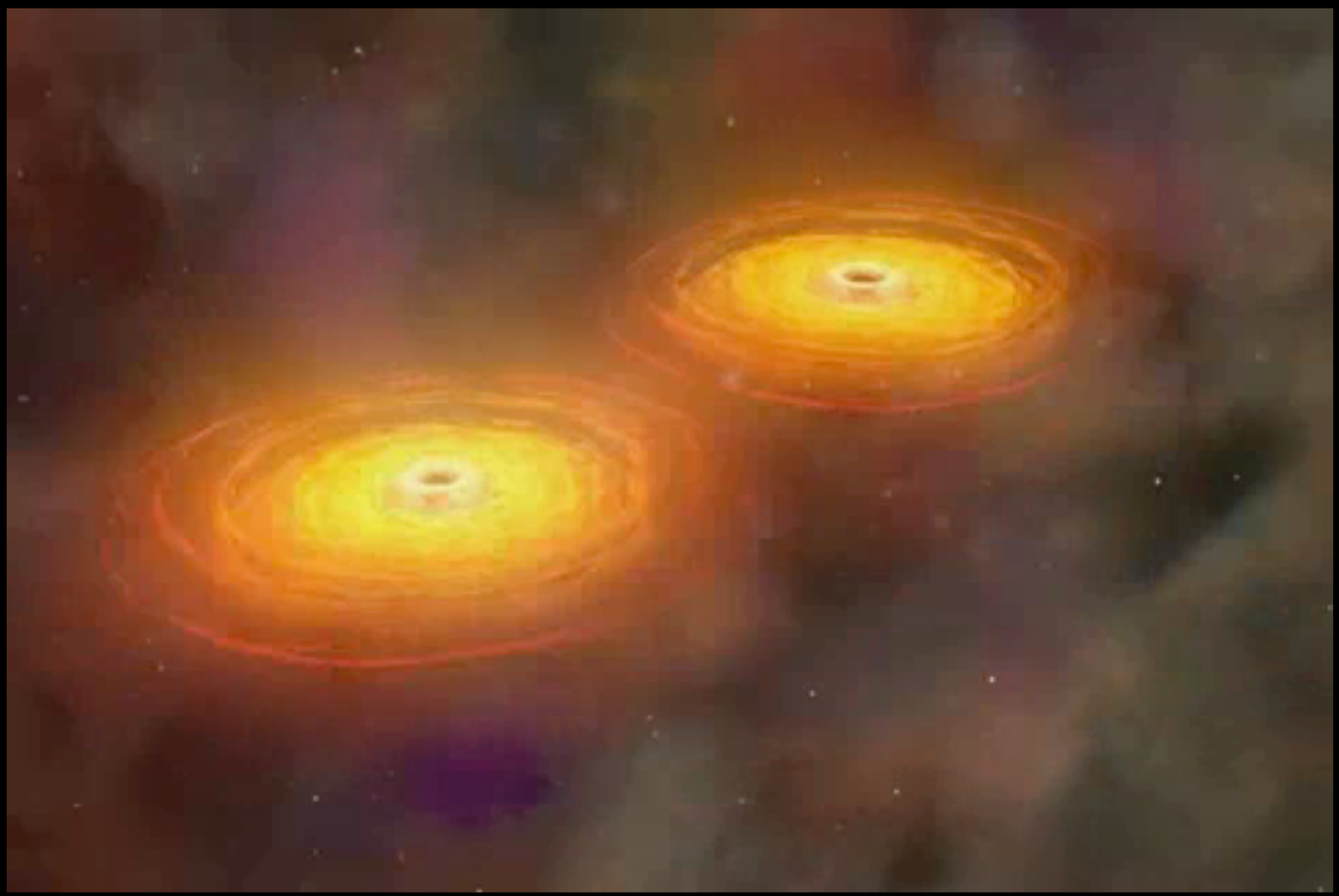
Risks to the solar system: Starburst encounters

- 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 themselves would be flooded with UV light from hot, bright massive stars. Bad for Earth even without a supernova!

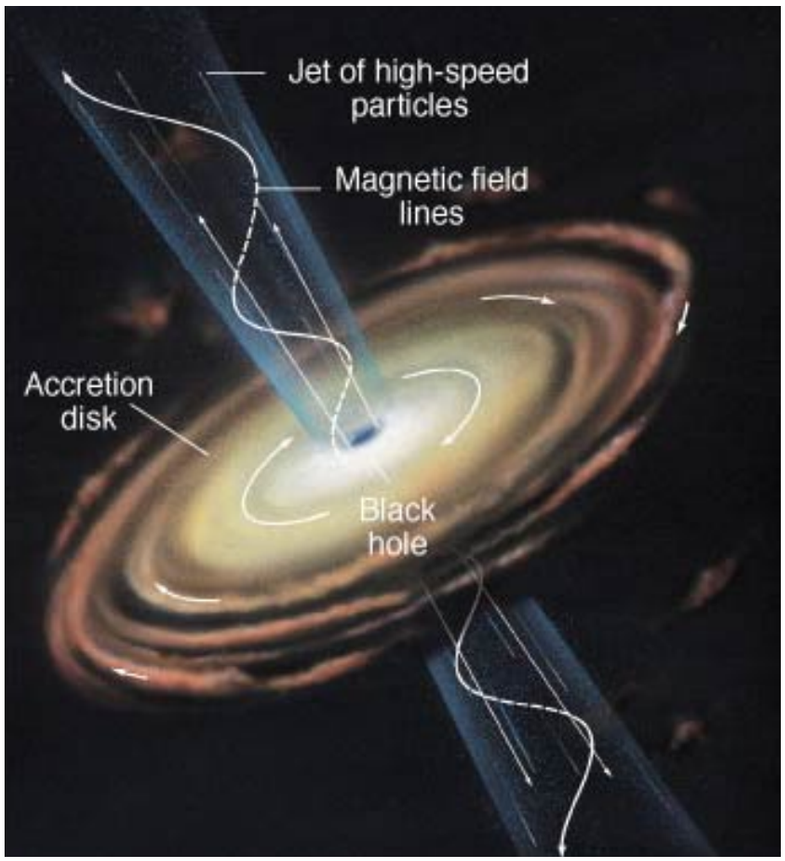
Risks to the solar system: Supermassive black holes



Both the Milky Way and Andromeda have supermassive black holes in their centers.
When the galaxies merge, those black holes will fall to the center of the merged galaxy and eventually merge themselves. Material from the galaxy merger will also fall to the center

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**



Active galaxies exhibit some combination of the following characteristics:

* Jets emanating from the nucleus
* High luminosity
* Rapid variability from compact energy source in the nucleus

The odds of colliding with the black hole are incredibly small, but if the solar system passed too close, it could be bathed in a lethal dose of X-rays or ejected from the galaxy by its gravity.

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.

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 Leslie 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?

Is the Universe out to get us?

Imagine

After getting flung a few billion years into the future by a 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 Leslie didn't mention how painful it would be, and you 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**

Prelude

Here at the University of Illinois...

we promise the Universe:
it's right there in the name!

Now, we deliver!

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

ILLINOIS

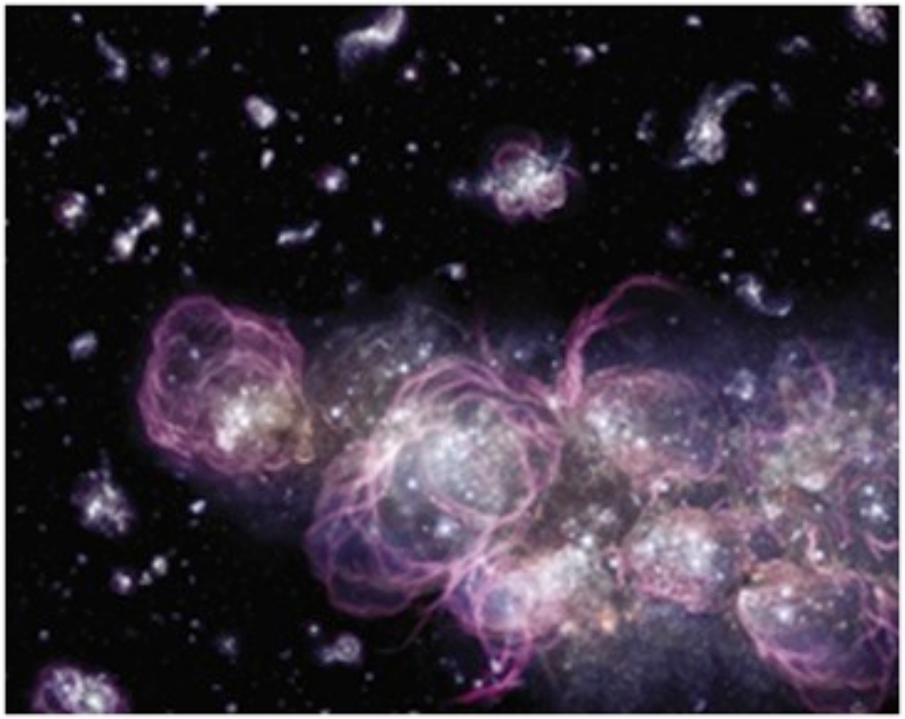
First, a little cosmological bragging rights

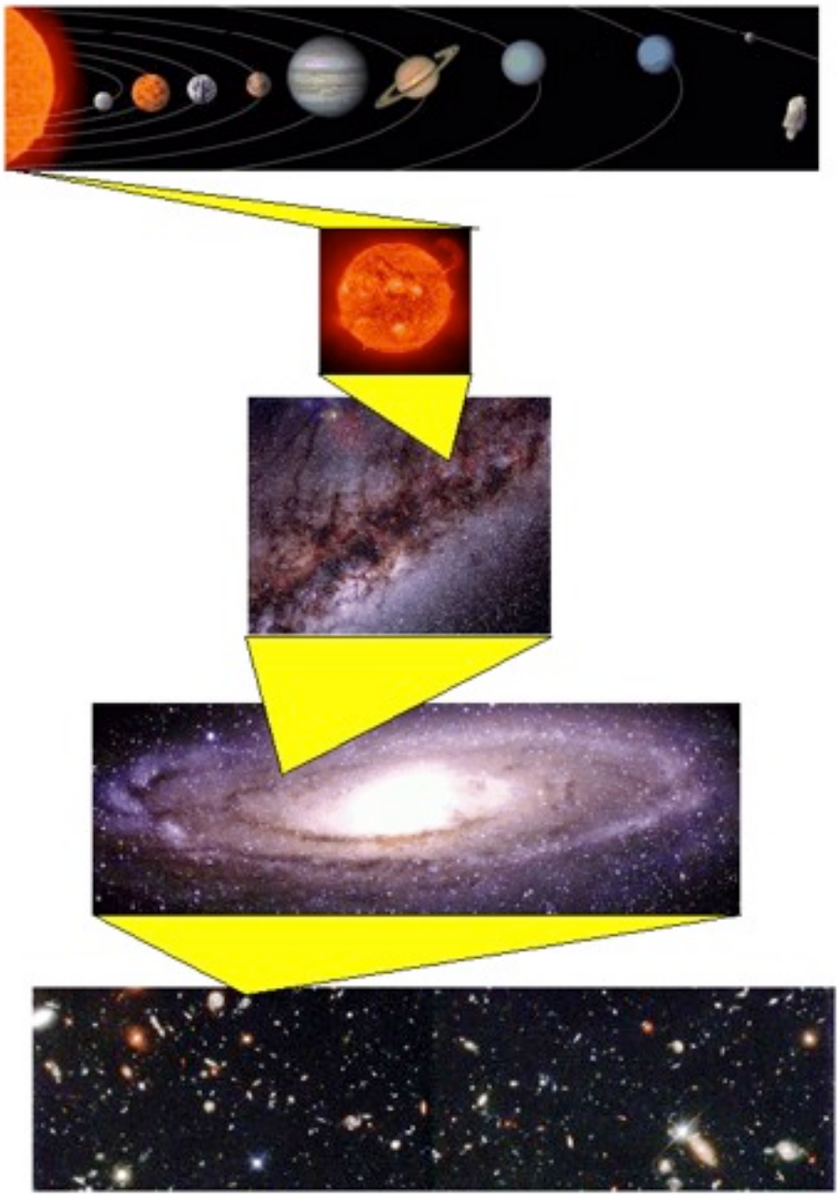
Cosmology

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?

Slices of the Universe

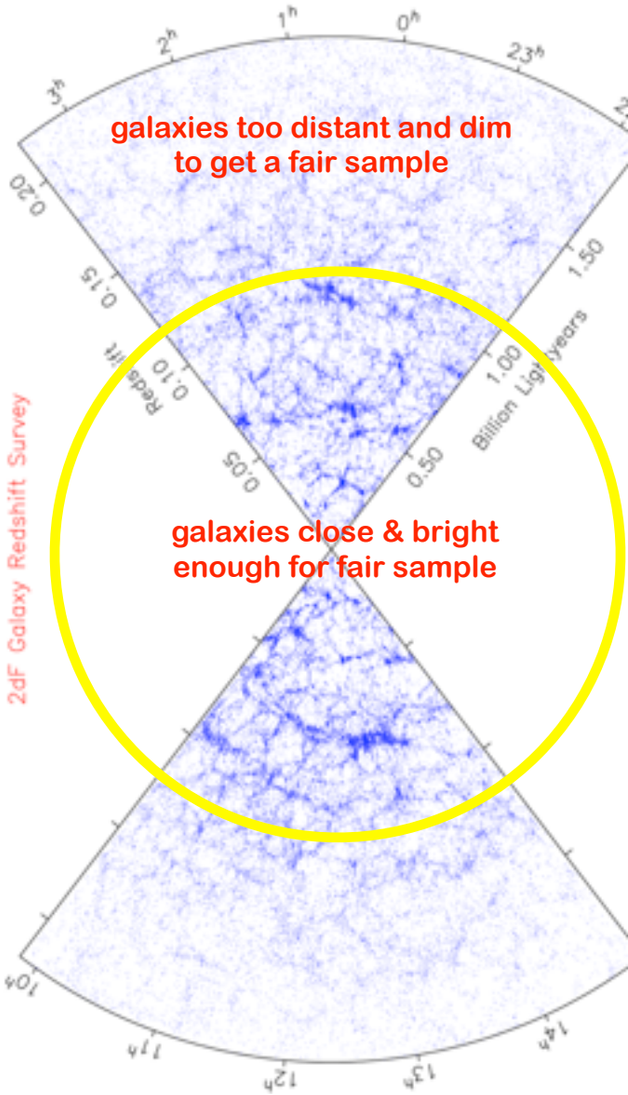
Map construction:

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

Focus on the innermost half of the region

What about most distant regions?

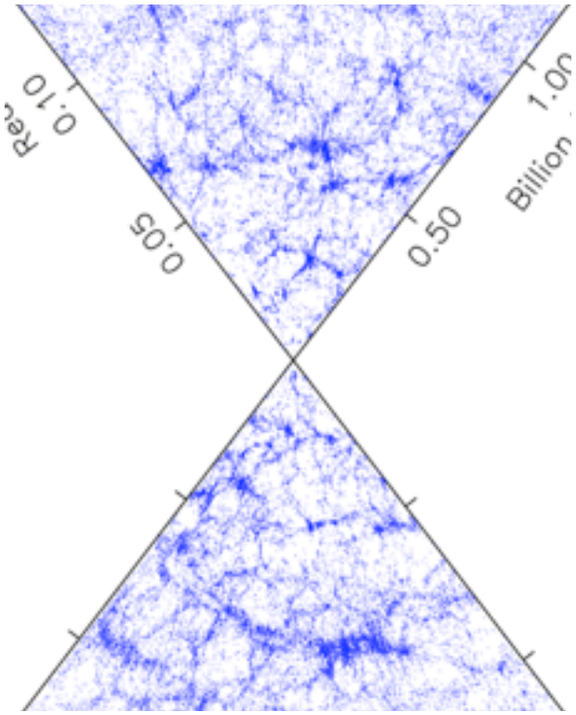
- galaxies so far away, can't see a representative sample
- looks like running out of galaxies, but really just seeing brightest ones: tip of the iceberg



Slices of the Universe

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

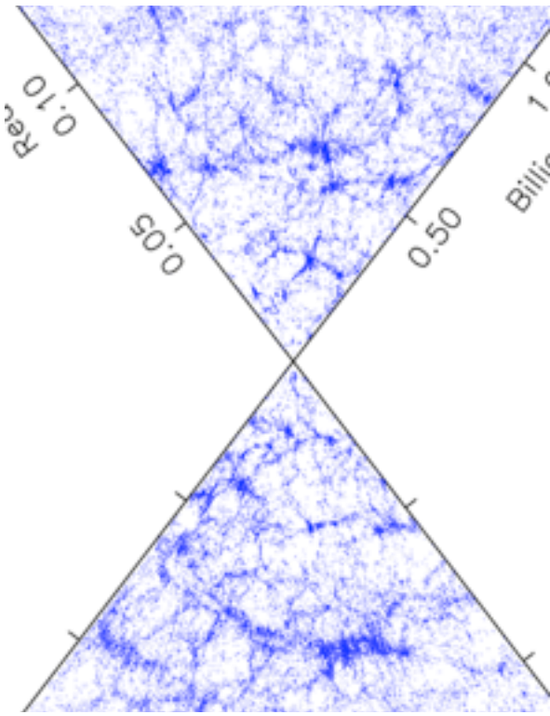
- on small scales, galaxies fill space unevenly
- some regions almost empty: "voids"
- some have a few galaxies near each other: "groups"
- some have huge numbers of galaxies in small region: "rich clusters"

The Large-Scale Structure of the Universe

Observations teach us that, on average the Universe today is

1. homogeneous: average properties same at all points

- matter smoothly fills universe, evenly distributed everywhere
- e.g., mass density anywhere is same as mass density everywhere!



and

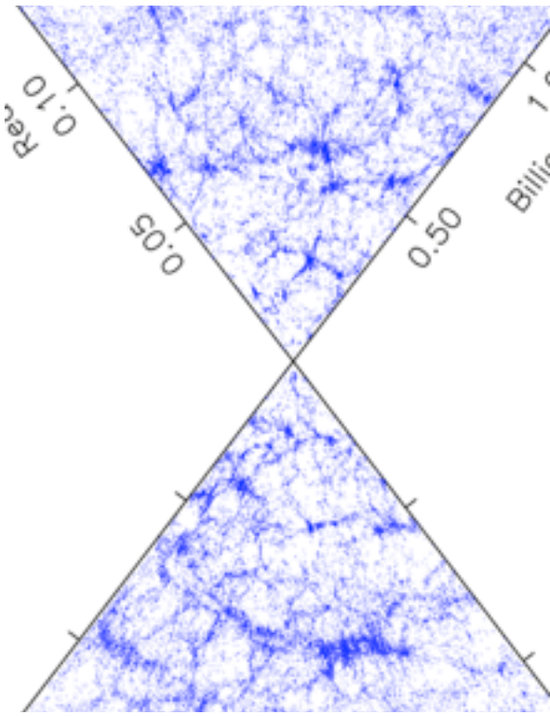
2. isotropic: looks same in all directions

-

The Large-Scale Structure of the Universe

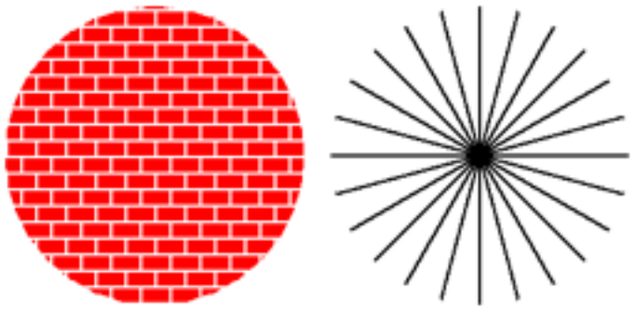
Universe is homogeneous & isotropic:

- the "cosmological principle"
- first guessed(!) by A. Einstein (1917)



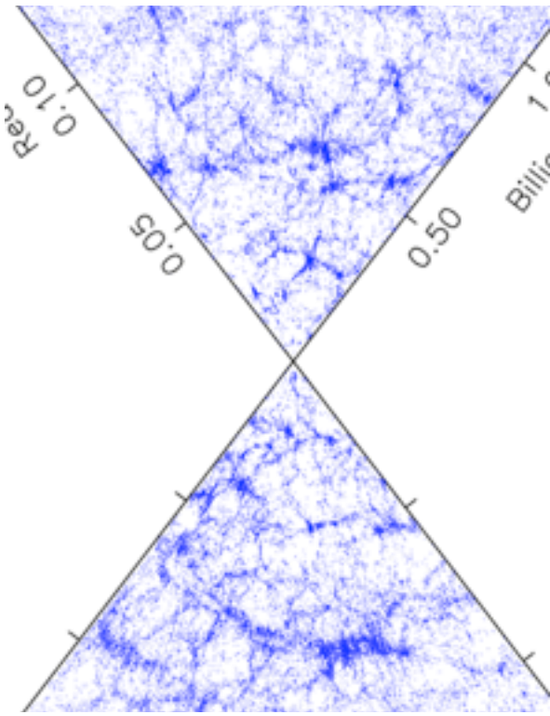
Do you need both?

- Q: e.g., how can you be isotropic but not homogeneous?
- Q: e.g., how can you be homogeneous but not isotropic?



Bottom Left: Homogeneous but not isotropic
Bottom Right: Isotropic but not homogeneous

The Large-Scale Structure of the Universe



Cosmo principle is a kind of cosmic democracy:

- Universe has no center, and no edge
- no special places, no special directions!

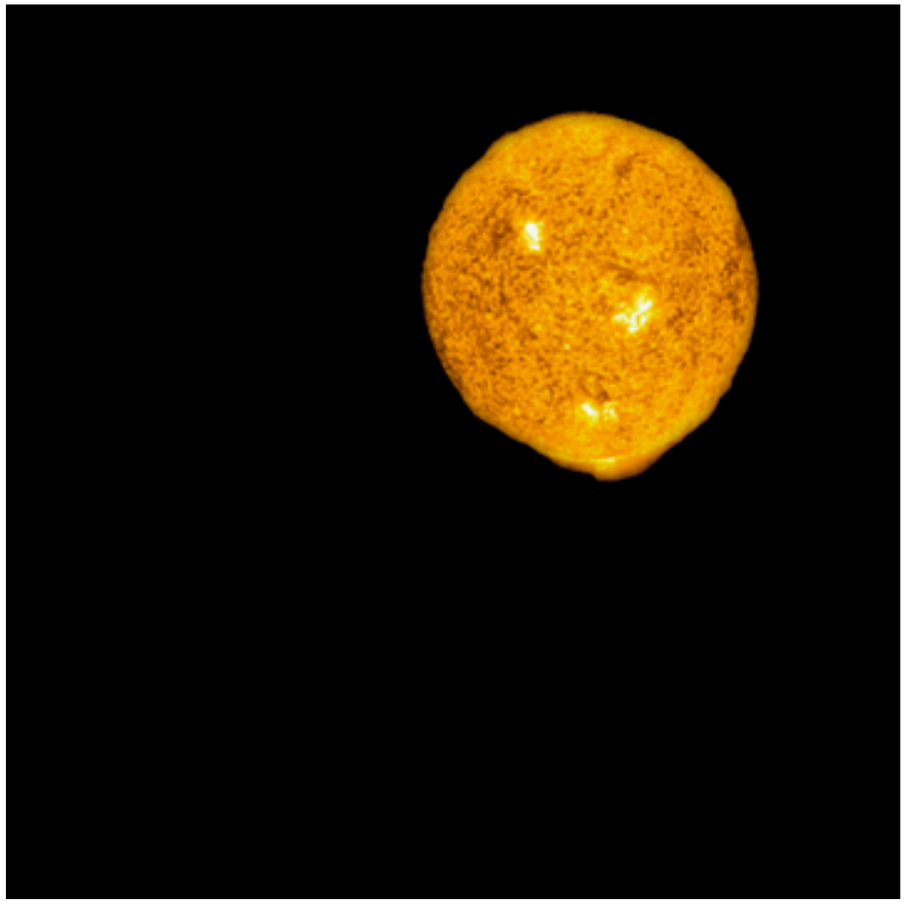
The Night Sky: Olber's Paradox

- What is special about the night sky?
- I mean the parts without stars... look carefully
- **Press A on your iclicker when your group has a guess.**

Imagine a universe that is
homogeneous:
filled smoothly with stars everywhere
infinitely old, and
infinitely large
What would the night sky look like in such a universe?

The Night Sky:
Olber's Paradox

If the Universe is infinite in age and extent, the sky should be bright



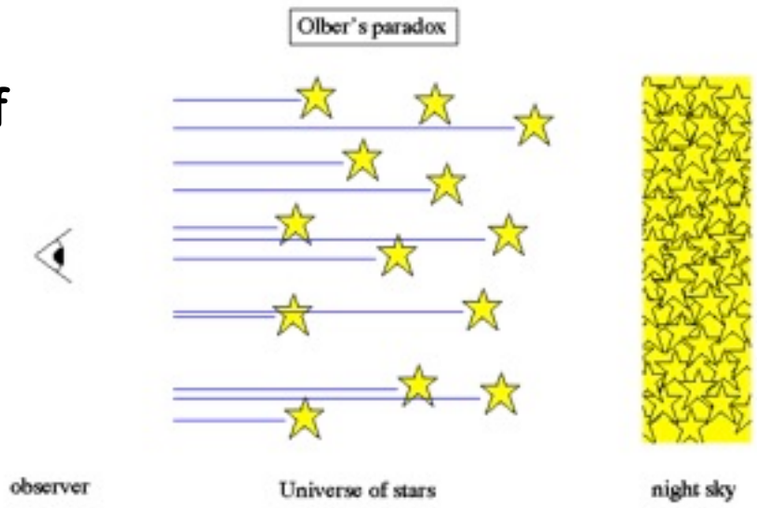
If the universe is indeed infinite, then there should be at least one star at every visible point in the sky lighting it up in all directions. Imagine standing at the center of a very thick forest: there is always a tree in your line of sight, regardless of what direction you are facing. If the universe was infinite, we would similarly see the light of a star at every point in the sky--this would also imply that the night sky would be blindingly bright with the light of infinite stars.

However, this is clearly not the case as our night time sky is (as you may have noticed) in fact dark. This paradox provides evidence that the universe is either expanding or has a finite history.

The Night Sky: Olber's Paradox

Thus: in an infinitely old and large universe:

- in any direction you look, that sightline lands on the surface of a star
- so the entire night sky should be as bright as the surface of a star!
- the entire sky should be as bright as the Sun!
- Obviously this is crazy!
- Q: so what's the lesson?



The Night Sky: Olber's Paradox

So: the darkness of the night sky contains important information about the universe:

- One of our assumptions must be wrong!
- In fact: the Universe has not existed forever.
- instead the Universe has a finite (non-infinite) age!
- the Universe had a beginning in time!