

# SCI199: Astronomy @ the Frontiers

Prof. Yanqin Wu

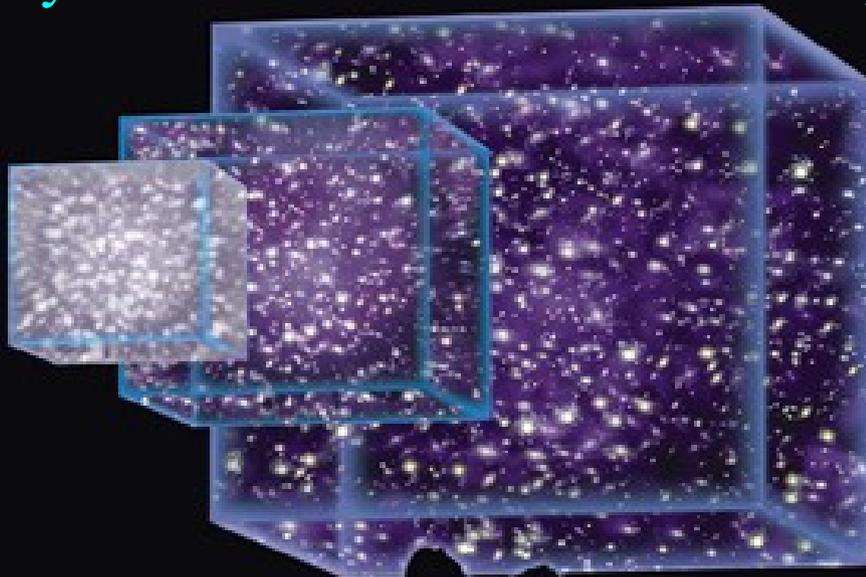
Research Specialties: stars and planets,  
origin and evolution of these bodies

Course web-site: [www.astro.utoronto.ca/~wu/SCI199](http://www.astro.utoronto.ca/~wu/SCI199)

pre-requisites:

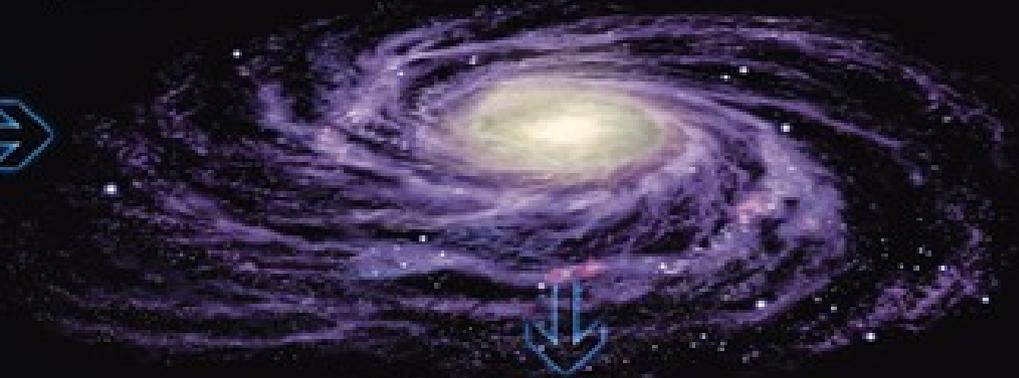
special permission: AST101, 121, 201

# Stars, planets, moons, asteroids, galaxies, groups of galaxies, clusters... every celestial bodies in the universe, and the universe itself



The universe has been expanding ever since its hot and dense beginning in the Big Bang. Each of the three cubes represents the same region of the universe, showing how the region expands with time.

Within a few billion years after the Big Bang, gravity caused local concentrations of matter to collapse into galaxies even while the universe as a whole continued to expand.



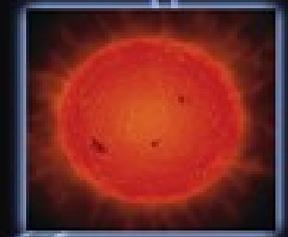
Galaxies like the Milky Way act as cosmic recycling plants: stars are made from the material in clouds of gas and dust within the galaxy, and stars return material to interstellar space when they die.



A star forms at the center of a collapsing cloud of gas and dust, and planets may form in the spinning disk that surrounds the young star.



Massive stars explode when they die, scattering the elements they've produced into space.



Stars shine with the energy produced by nuclear fusion in their cores; the fusion also creates heavier elements from lighter ones.

The Earth was built with elements produced in stars that lived and died in the Milky Way before our solar system formed.

# What is this course about?

It's not about facts, it's about scientific literacy.

Literacy: (OED)

The quality or state of being literate; knowledge of letters; condition in respect to education, *esp.* ability to read and write. Also *transf.*

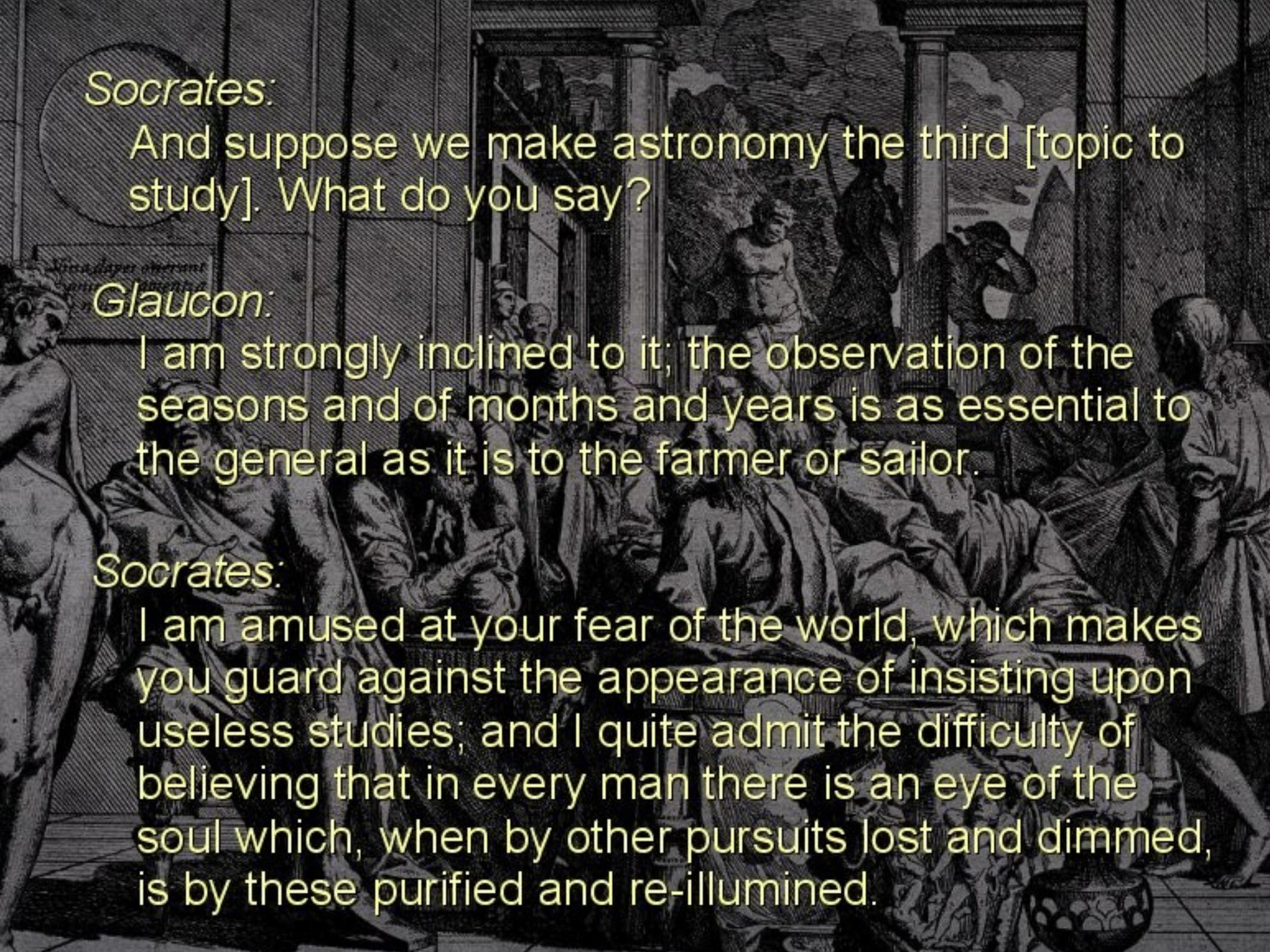
common-sense about nature

Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions.

Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (National Science Education Standards, page 22)

## Why astronomy?

Trigonometry  
digital camera  
radio-isotope  
nuclear energy  
medical imaging  
climate change...



*Socrates:*

And suppose we make astronomy the third [topic to study]. What do you say?

*Glaucon:*

I am strongly inclined to it; the observation of the seasons and of months and years is as essential to the general as it is to the farmer or sailor.

*Socrates:*

I am amused at your fear of the world, which makes you guard against the appearance of insisting upon useless studies; and I quite admit the difficulty of believing that in every man there is an eye of the soul which, when by other pursuits lost and dimmed, is by these purified and re-illuminated.

# Specifically, for you

the cost of learning:

the cost of not learning:

Every minute counts.  
It doesn't pay to squander.

# What does it take to get a good grade?

1) Presentations: 25%

1 short (1<sup>st</sup> term) + essay

1 long (2<sup>nd</sup> term) + essay

2) 10 assignments: 30%

MasteringAstronomy

(textbook: Cosmic Perspective, 5<sup>th</sup> edition,  
by Bennett et al., Pearson Addison-Wesley  
bookstore discount package: ISBN 0135067928)

3) Term test: 15%

at the end

**4) *Participation*: 30%**

attend lectures and mental participation

(23%)

(7%)

## Practicalities:

1) Essays are to be submitted to:  
[www.Turnitin.com](http://www.Turnitin.com)

course ID: (given in class)

password: (given in class)

*for how to sign-in, see the essay section in  
[www.astro.utoronto.ca/~wu/SCI199/presentations.html/](http://www.astro.utoronto.ca/~wu/SCI199/presentations.html/)*

2) assignments distributed, completed and graded on  
[www.masteringastronomy.com](http://www.masteringastronomy.com)

courseID: (given in class)

student ID: 99..... (your 9 digit student numbers)

*for how to register, download the instructor .ppt file from  
[www.masteringastronomy.com/site/tours/getting-started.html](http://www.masteringastronomy.com/site/tours/getting-started.html)*

# Overview of the Universe

After thousands of years of curiosity, we now stand at a special point in history:

- 1) we now know what stars are and how far they are
- 2) we now know what “the Milky Way” is
- 3) we now know why stars shine and whether they die
- 4) we now know quite a bit about planets (around our and other stars)
- 5) we now know the universe is 14 Gyrs old
- 6) we are getting to understand how things arise in this universe

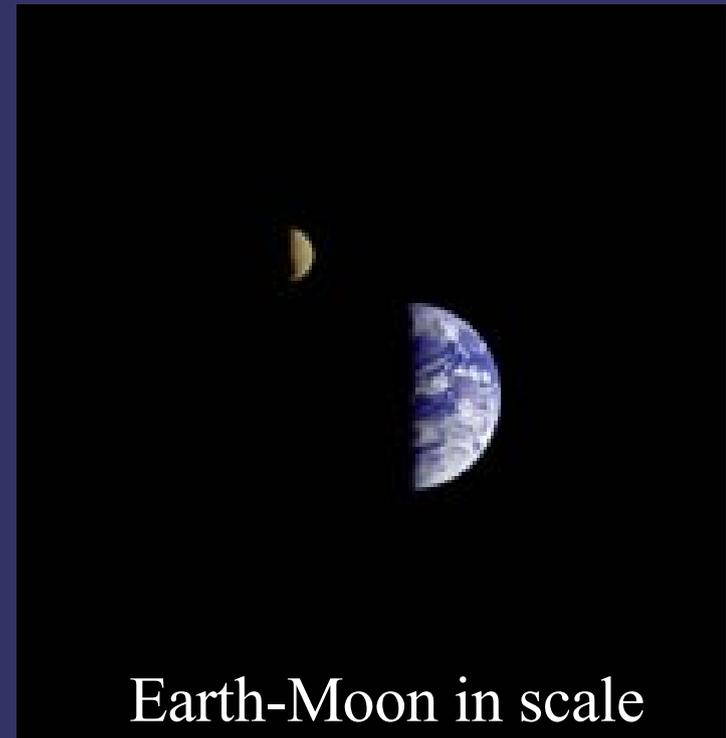
Earth: our home planet

We know:

The Earth spins around its axis

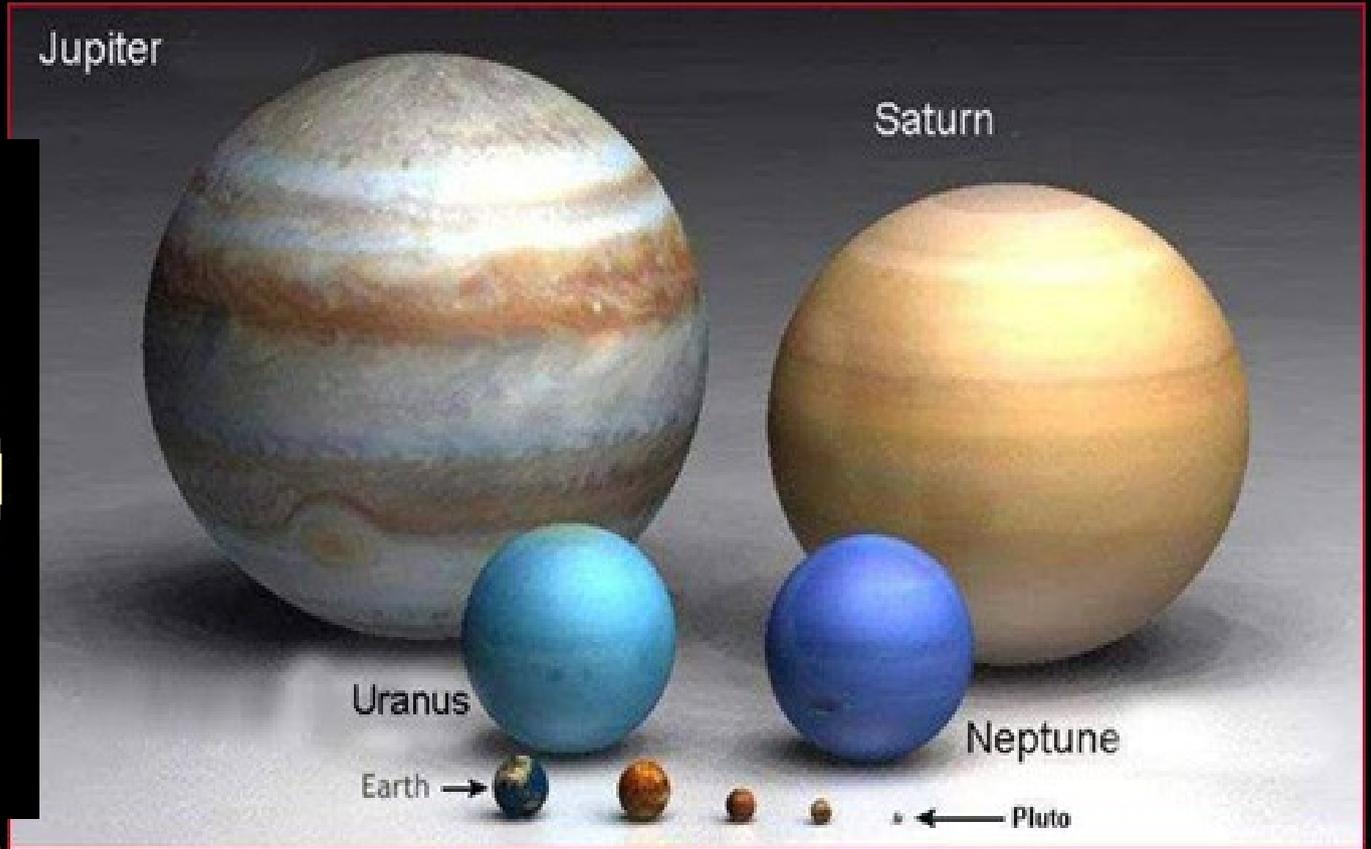
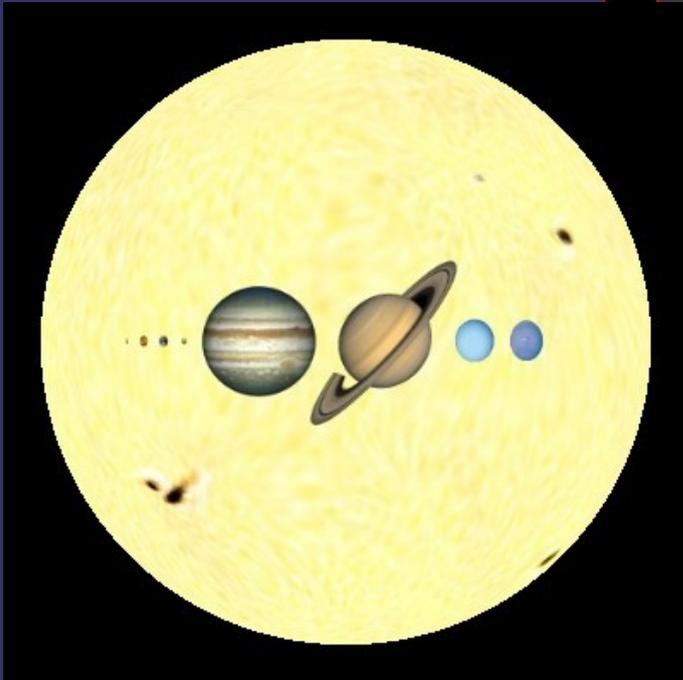
The Moon orbits around the Earth

Both the Earth and the Moon go around the Sun



# The solar system: our little oasis

Object sizes in scale.



All planets spin

Many of them have moons

They all orbit the Sun in the same sense, in a plane.

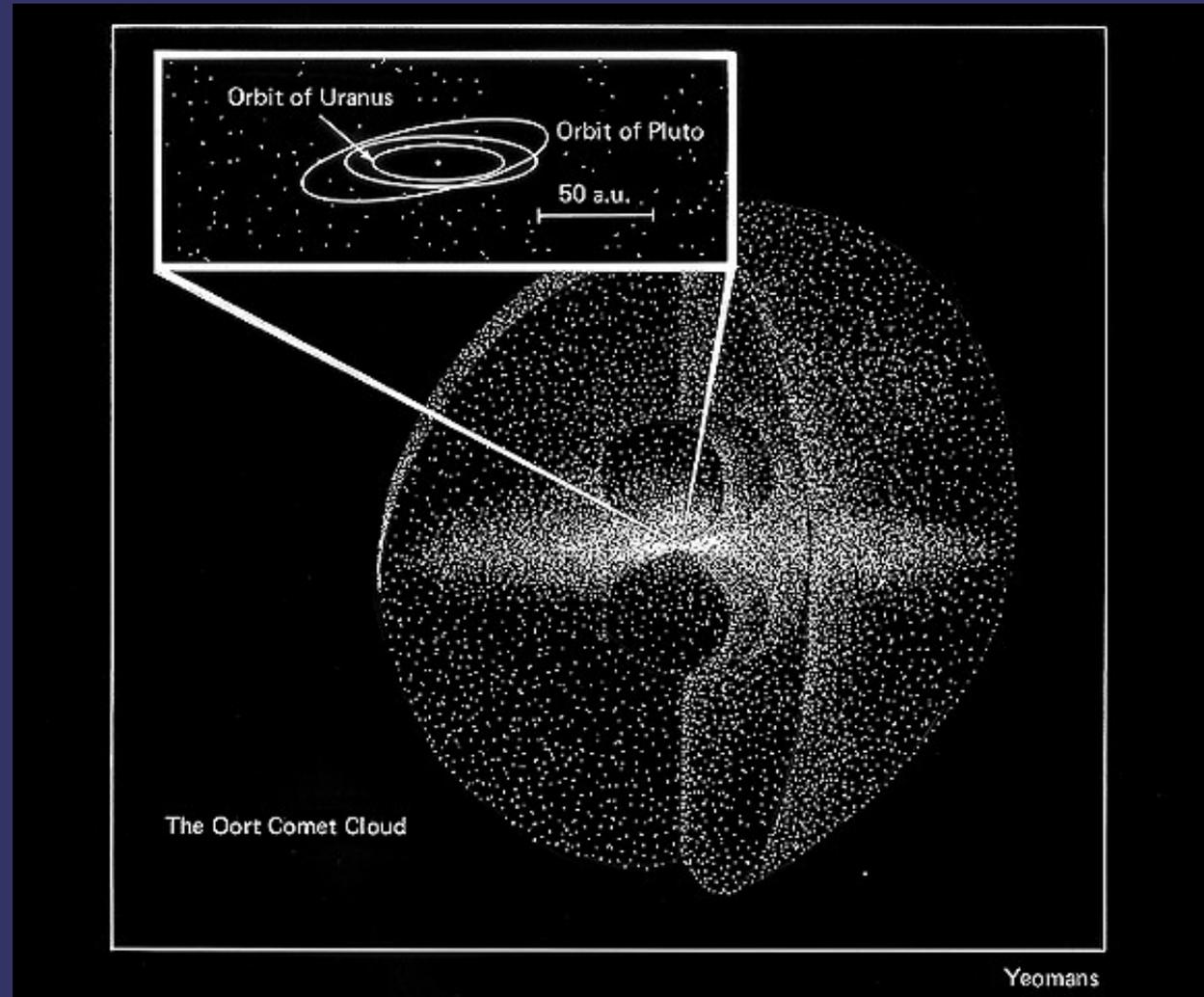
1 astronomical unit (1 AU)

**Table 1.1 Solar System Sizes and Distances, 1-to-10-Billion Scale**

<i>Object</i>	<i>Real Diameter</i>	<i>Real Distance from Sun (average)</i>	<i>Model Diameter</i>	<i>Model Distance from Sun</i>
Sun	1,392,500 km	—	139 mm = 13.9 cm	—
Mercury	4,880 km	57.9 million km	0.5 mm	6 m
Venus	12,100 km	108.2 million km	1.2 mm	11 m
Earth	12,760 km	149.6 million km	1.3 mm	15 m
Mars	6,790 km	227.9 million km	0.7 mm	23 m
Jupiter	143,000 km	778.3 million km	14.3 mm	78 m
Saturn	120,000 km	1,427 million km	12.0 mm	143 m
Uranus	52,000 km	2,870 million km	5.2 mm	287 m
Neptune	48,400 km	4,497 million km	4.8 mm	450 m
Pluto	2,260 km	5,900 million km	0.2 mm	590 m

If the Earth's orbit around the Sun is the size of a dinner plate, how big would the orbit of Pluto be?

- 1) size of a large dinner plate
- 2) size of a small class-room
- 3) size of down-town Toronto
- 4) size of Canada

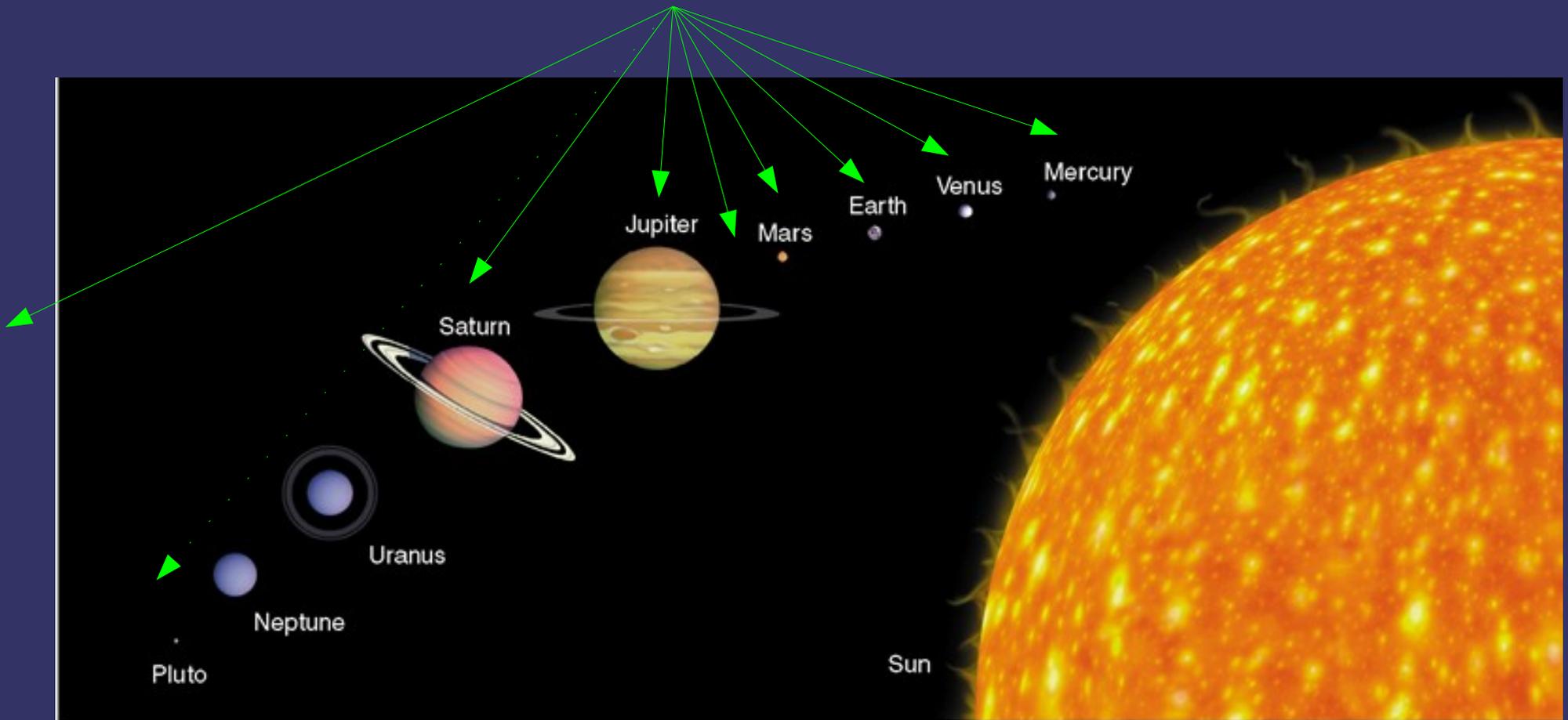


The complete solar system is much, much bigger ....

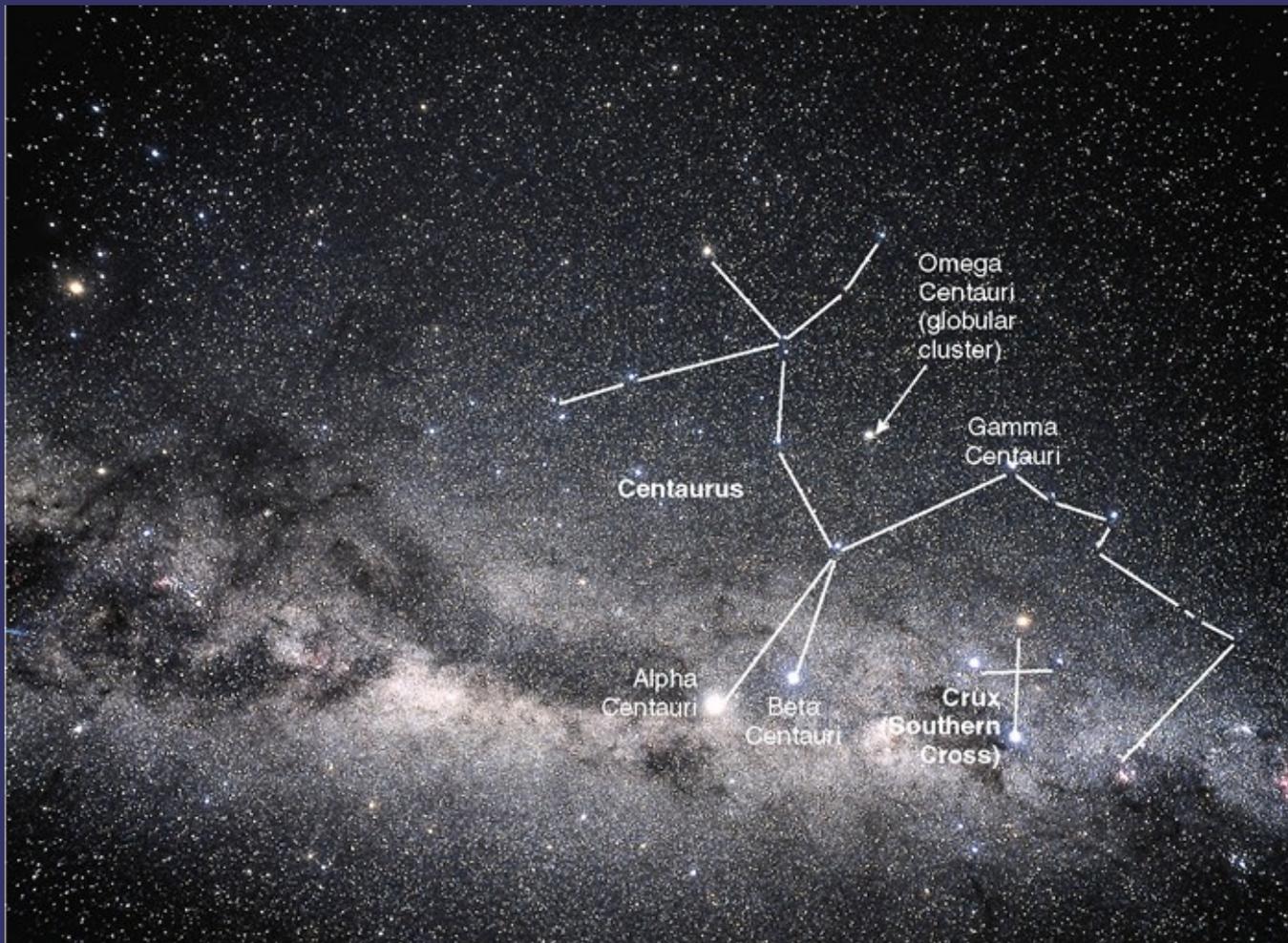
The furthest point human has been...



# The Solar system: visited by man-made objects



the closest star system to us -- Alpha-Centauri  
4.4 lightyears



Distance = speed x time

1 lightyear = distance light travels in a year  
= speed of light x 1 year

~ 10,000,000,000,000 kilometers  
(~ 10 trillion kilometers  
or  $10^{13}$  kilometers)

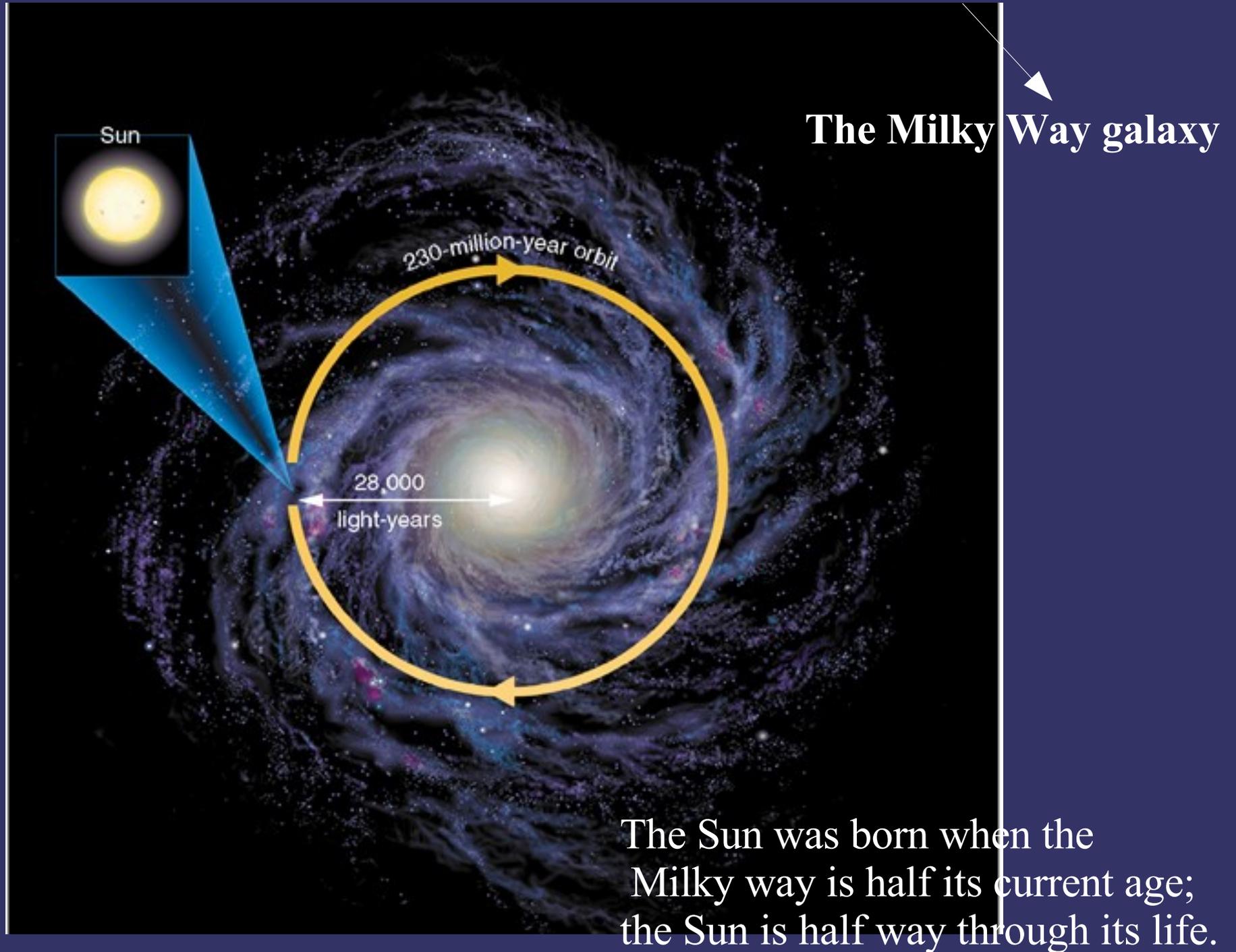
If the Earth's orbit around the Sun is the size of a dinner plate, and Pluto's orbit size of this room, how far would the nearest star be?

- 1) here to CN Tower
- 2) here to Pearson airport
- 3) across lake to Niagara Falls
- 4) Toronto to Vancouver

Light takes 8 minutes to travel from Sun to Earth, but takes 4.4 yrs to get to the nearest star. After Pluto, it's another factor of 1000.

What is in-between us and the nearest star?

# The Sun goes around the centre of the Galaxy





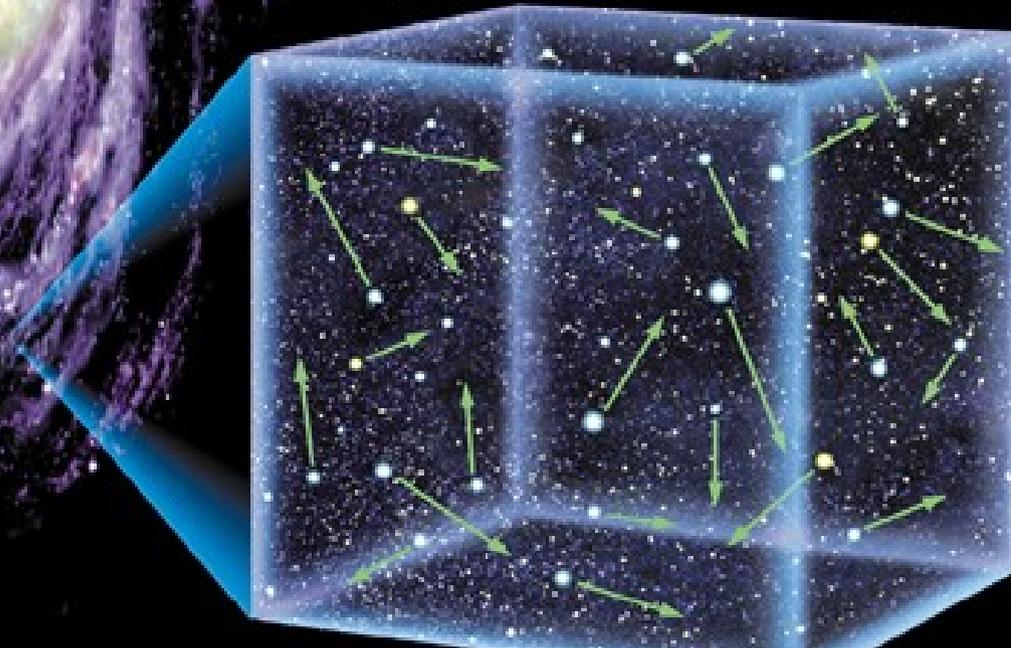
Capital Reef National Park  
(c) Wally Pacholka

# How many stars in the Galaxy?

Number of sand grains in a sandpit  
~ 100 billion

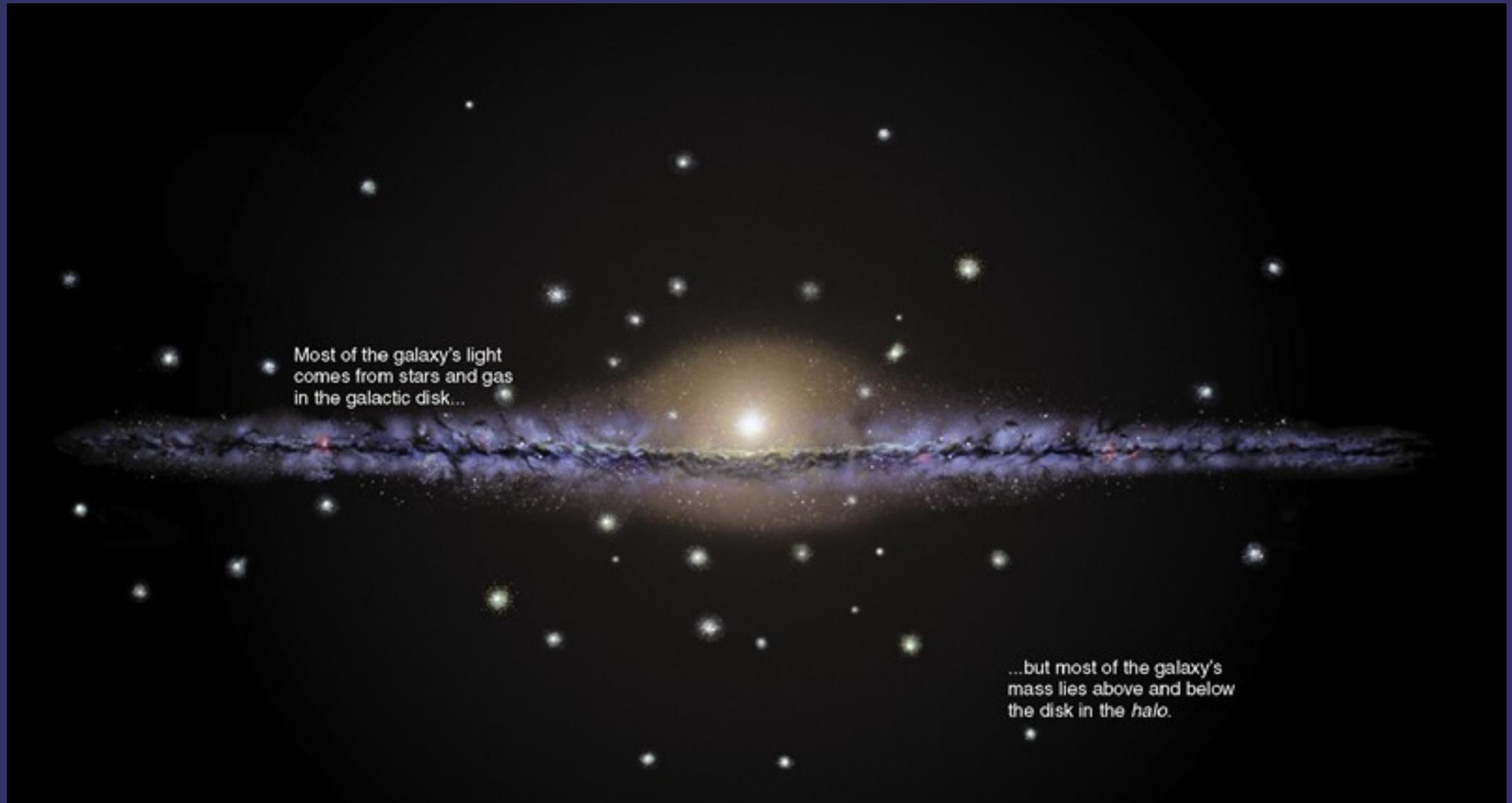


The box represents stars and their motions in the local solar neighborhood.



~ 100 billion ( $10^{11}$ ) stars

# Galaxies contain stars, gas, dust, dark matter...



Artist's conception of a galaxy, stars lie at different locales and orbit around the galaxy.

# Some (unconventional) galaxies on the sky







A galaxy is an island in the universe.

The space is very, very empty outside a galaxy.

Galaxies form communities.

A small community is called 'group' (groups of galaxies)



The Milky Way galaxy is one of the largest galaxies in our local group (~100)

Groups of galaxies come in clusters (clusters of galaxies)

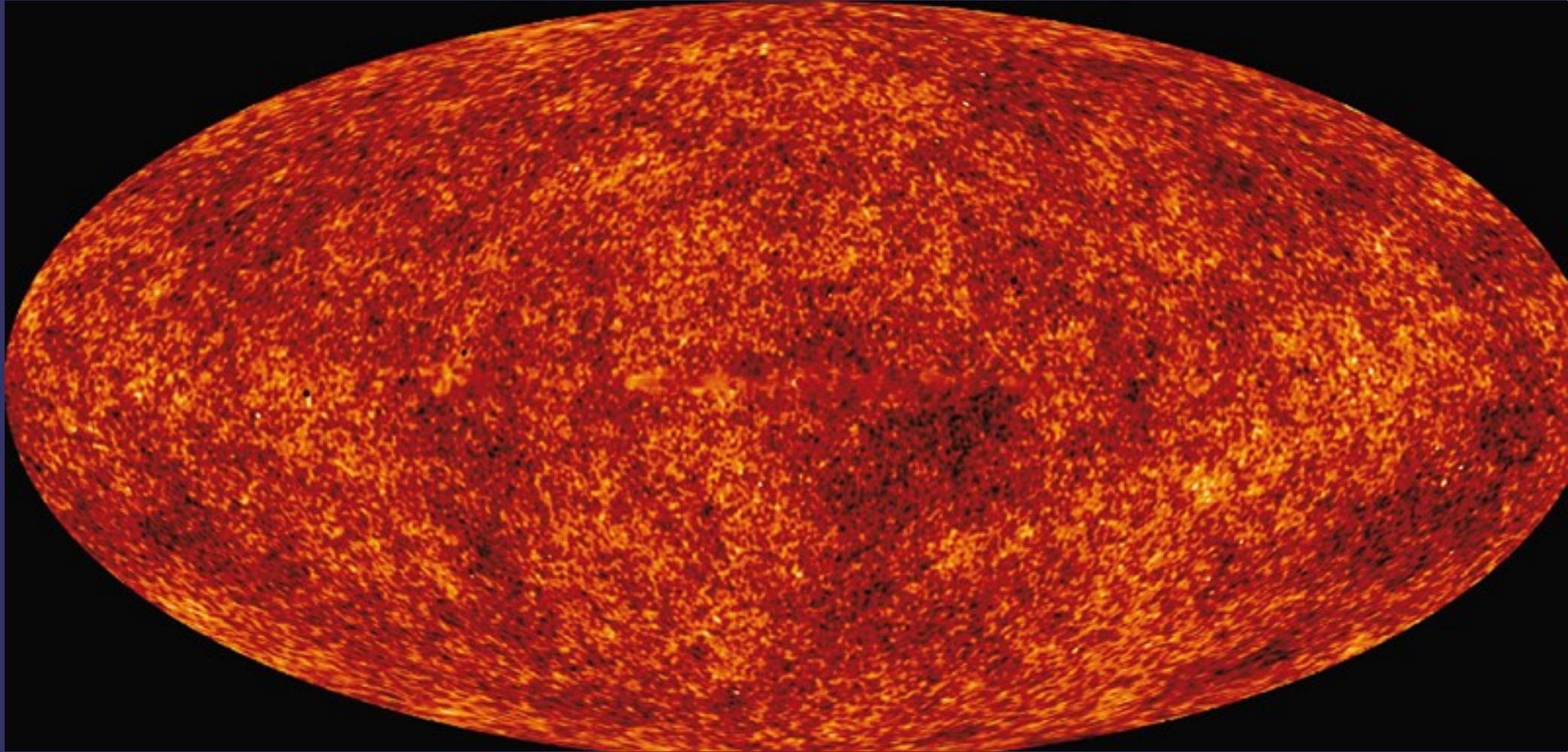


We belong to the Virgo supercluster, which contains  $\sim 100$  groups of galaxies

A cluster of galaxies is an island universe.

The space is very, very empty  
outside the cluster (void).

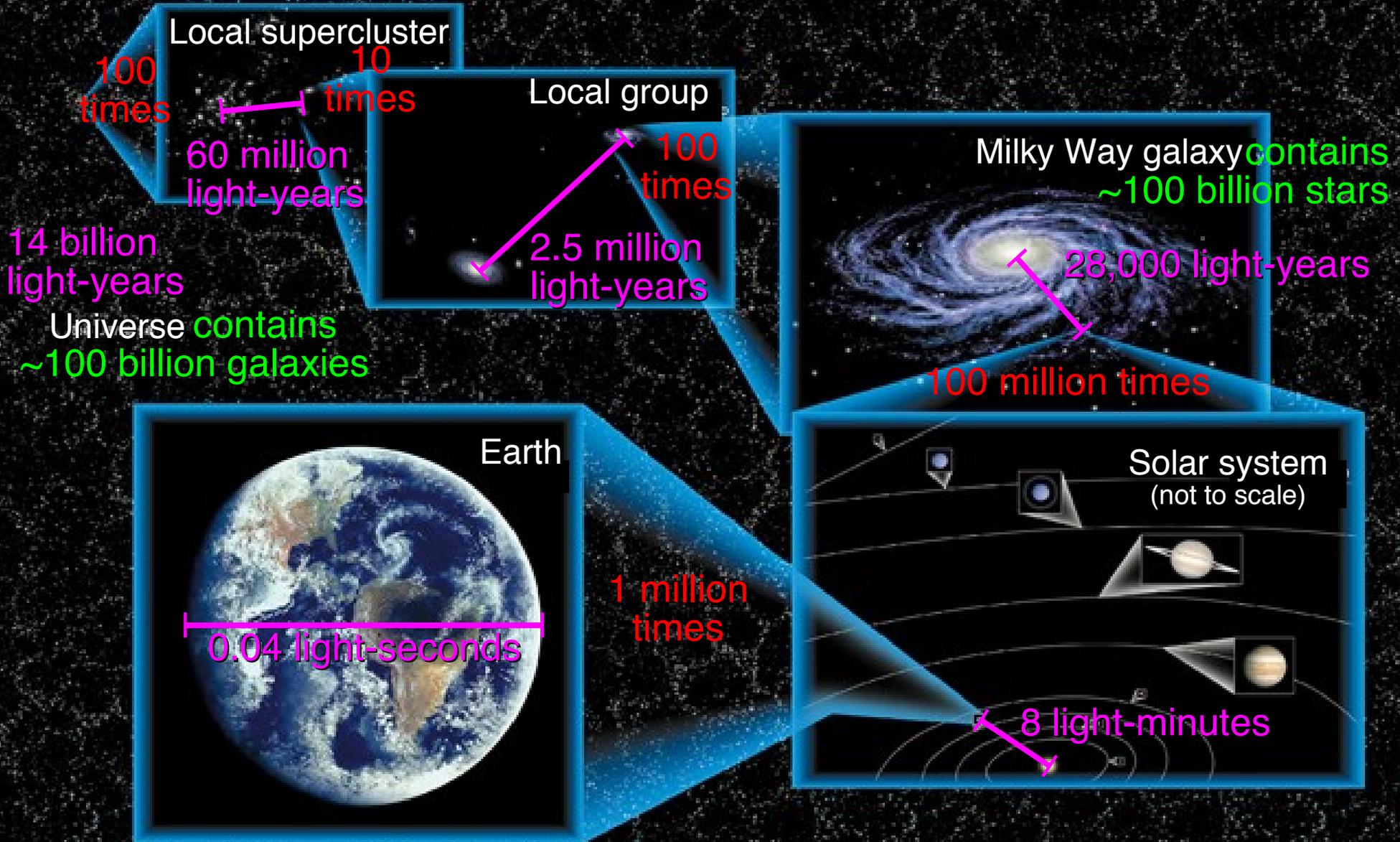
The universe  
made of clusters of galaxies, and voids

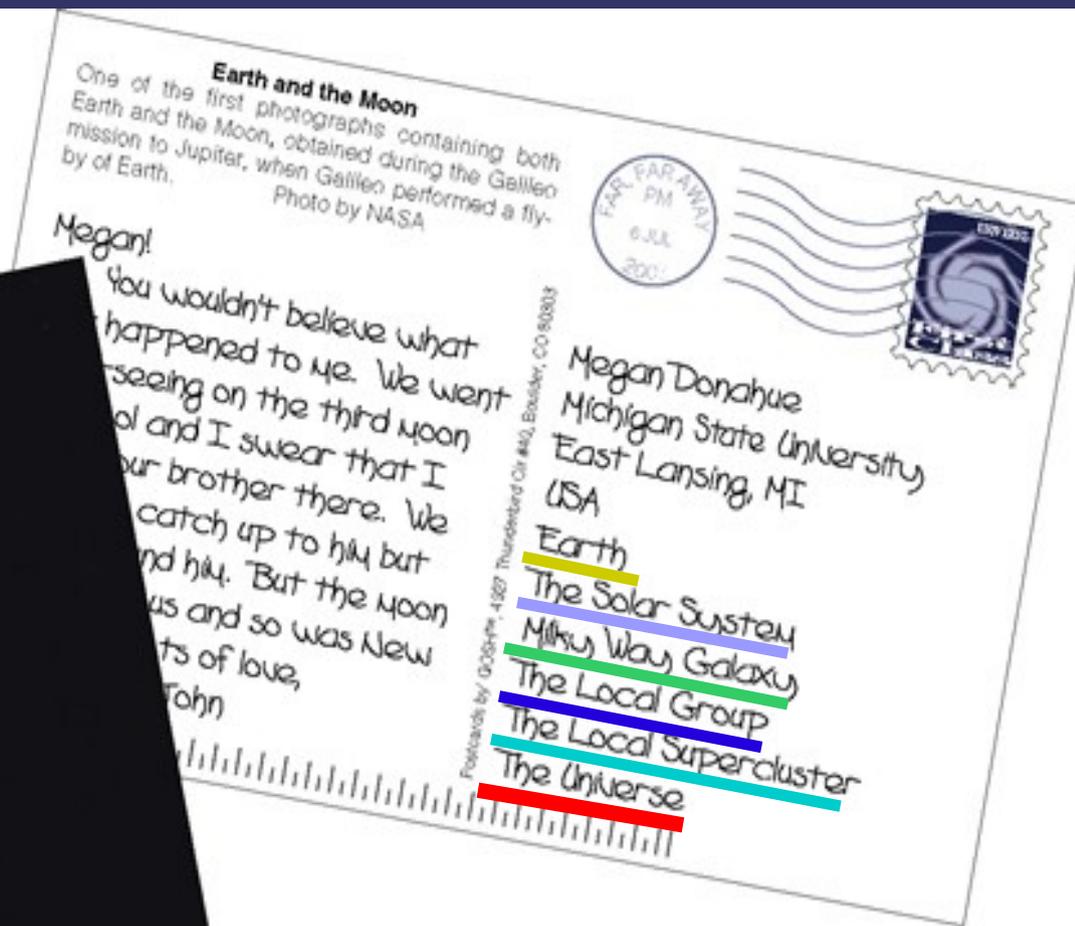


# Our Cosmic Address



# Light takes 14 Billion years to travel to the end of our universe.





# Overview of the Universe

We are at a lucky time:

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How many intelligent lives are there in the universe?

1) how likely evolution gives rise to intelligence?

2) how likely an Earth-like planets harbours life?

3) how many Earth-like planets each star owns?

4) how many stars are in a galaxy?

5) how many galaxies are in the universe?

Multiplying all together ---- the Drake's equation

If we are born 100 years later....

1) we might understand why the universe is as it is

2) we might know whether the Solar System is unique

3) we might know whether there is life beyond

....