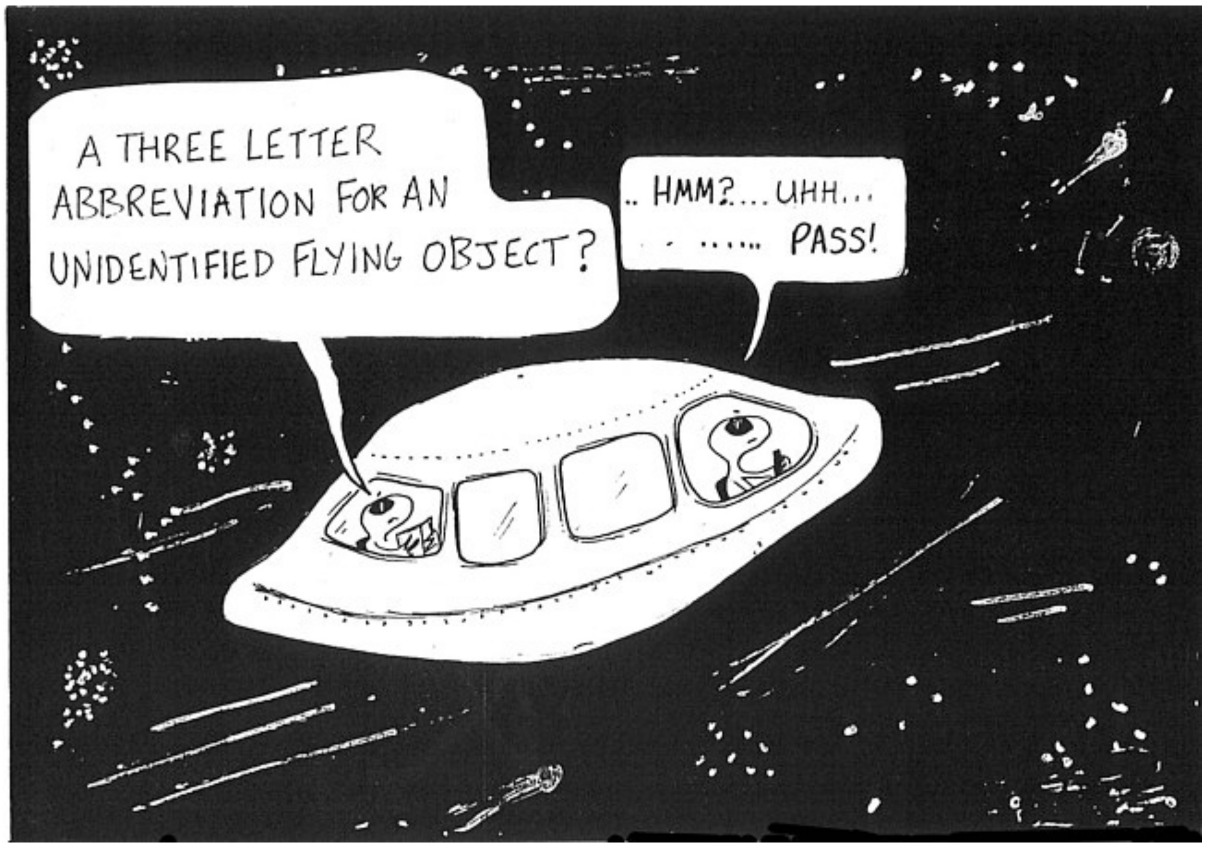
ASTR 380

The Universe: the context for Life



Outline

- Objects in the universe
  Planets
  Stars
  Galaxies
- Atomic elements; what is needed?

To Add Flavor

- First few minutes of class, will endeavor to answer any astronomy questions (even outside topic of class)
- If you have DVDs or Web videos relevant to current topic of class, I may play them

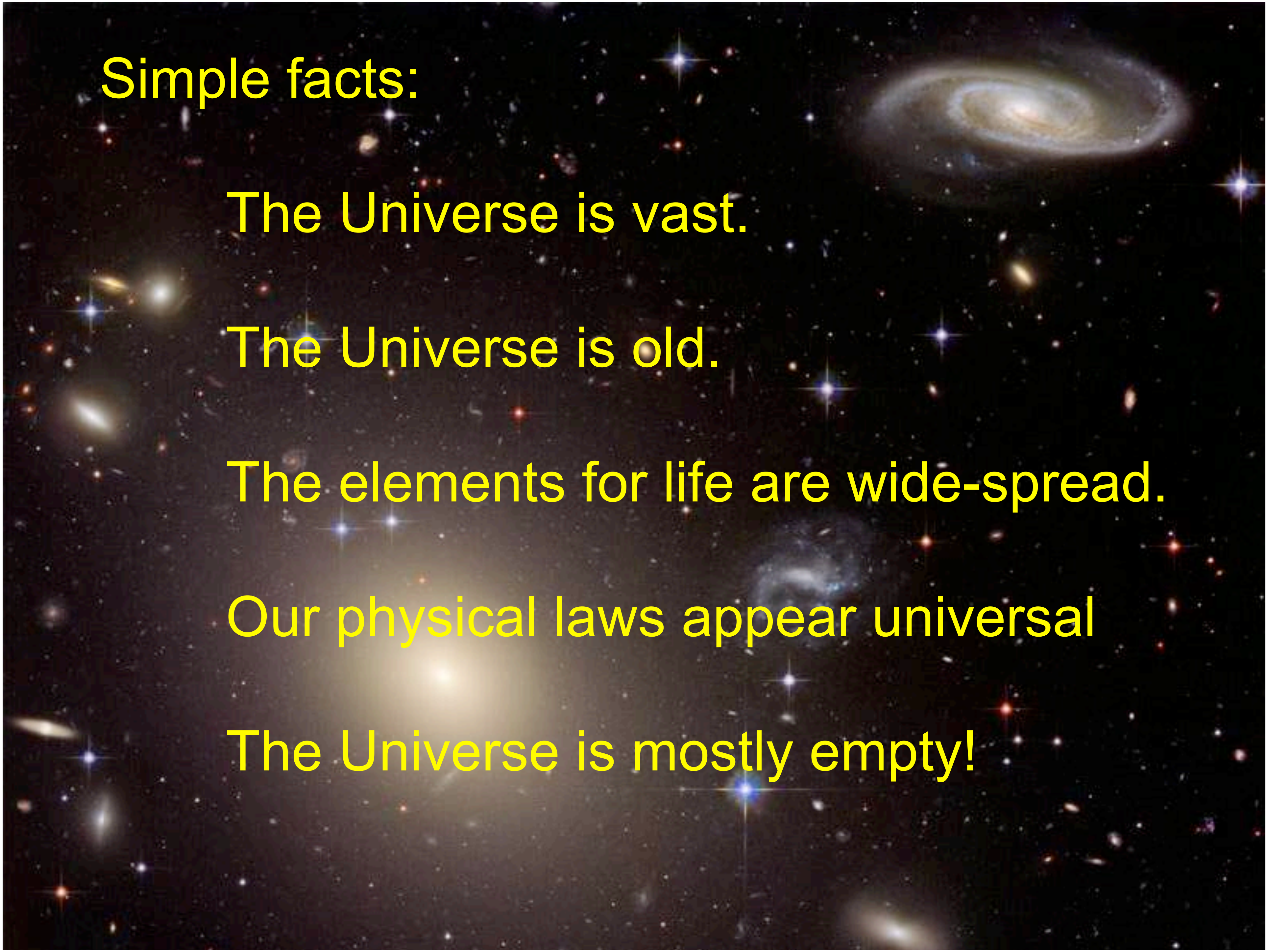
  Must be <1 minute long

  Get to me at least a day in advance, so I can evaluate

  Have fun! Doesn't have to be serious :)

Space is big. You just won’t believe how vastly, hugely, mind-boggling big it is. I mean, you may think it’s a long way down the road to the chemist’s, but that’s just peanuts to space.

Douglas Adams

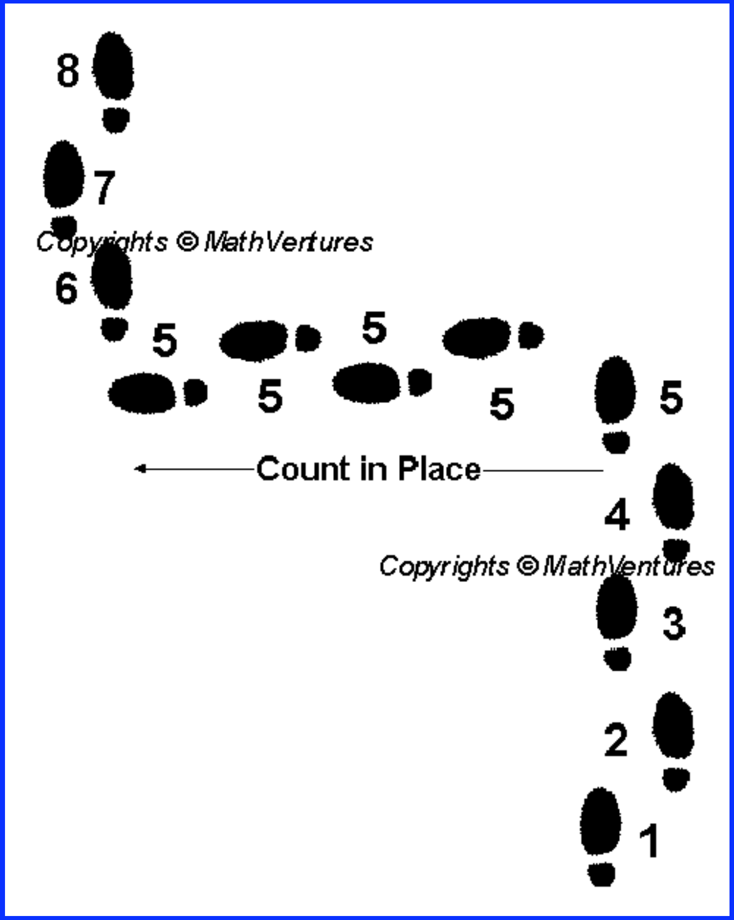

Simple facts:
The Universe is vast.
The Universe is old.
The elements for life are wide-spread.
Our physical laws appear universal
The Universe is mostly empty!

Measuring Distances

- When we talk about the scale of the universe, number of objects, etc., we need to measure distances
- But we can’t visit these places
- How can we know? What methods can we use?

Baseline: Direct Measurement

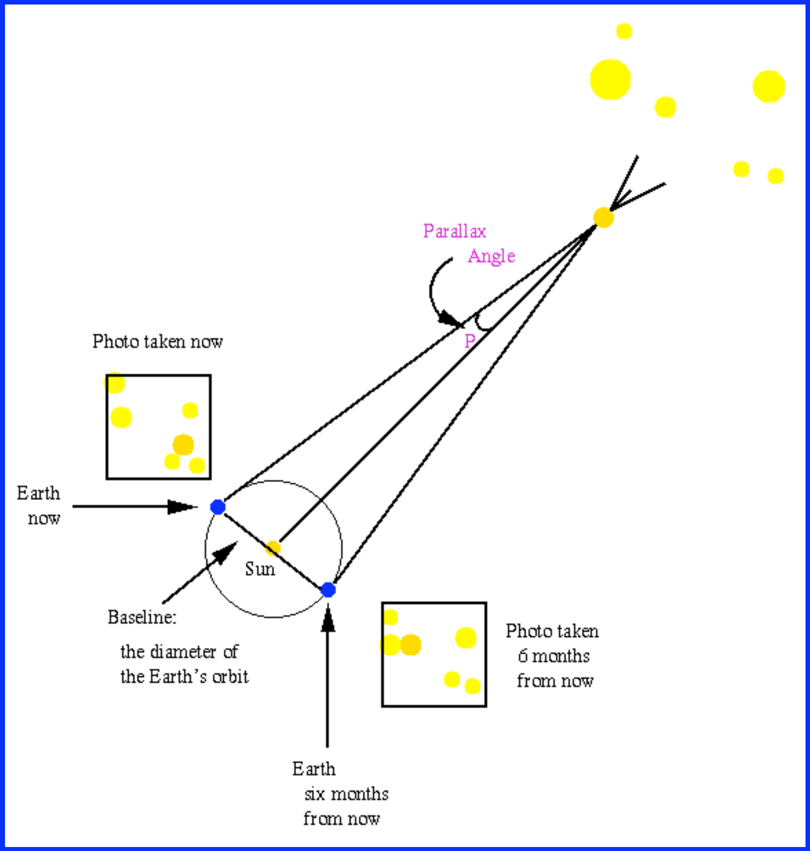
- Must always start with direct measurement
- In case of Eratosthenes, had soldiers pace out distance
- But can't walk into space...



From MathVentures

Geometry: Parallax

- Use Earth orbit; different views at different times of year
- Nearer stars seem to move more
- Try it: cover one eye, then the other
- Useful for "nearby" stars <few hundred lyr away



http://www.astro.umd.edu/resources/introastro/images/parallax.gif

Standard Candle

- Source of known brightness
- How bright it seems tells you its distance
- Issue: how do you find objects of known brightness?
- Examples: Cepheid variables; special type of supernova
- Direct; parallax; standards part of "distance ladder"

http://pdgusers.lbl.gov/~pslii/uabackup/source_files/image/universe_16.jpg

What about our Solar System?

It's a comfortable size…

If we scaled the sun to be the size of a basketball…
Say 30 cm across….

Then the Earth would be about 3 mm across and located about 30 meters away.

Jupiter would be 3 cm in diameter and located about 150 meters away.

Neptune would be about 1 cm at a distance of 1 km.

An inventory of our Solar System

There are a variety of places in the Solar System where life could possibly have arisen.

There is no place that is currently similar to Earth.

Our Solar System can be used to test other possible environments where different from our own might arise….

An inventory of our Solar System

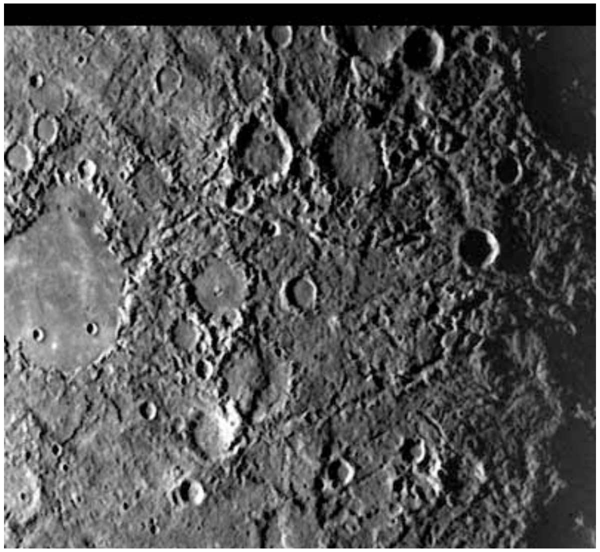
Our Solar System contains:

- the Sun
- planets (and minor planets)
- moons
- comets
- asteroids
- dust

An inventory of our Solar System

Mercury:

- close to the Sun
- rocky
- nearly no atmosphere
- hot on the Sun side
- cold on the dark side
- no reasonable chance of liquid water



An inventory of our Solar System

Venus:

Rocky surface
thick atmosphere
very hot due to greenhouse effect
no liquid water
"Earth's Twin" in mass and other ways

An inventory of our Solar System

Earth:
Rocky surface
liquid water
fun place to live

An inventory of our Solar System

Mars:

- rocky surface
- evidence of water ice and water flow
- thin atmosphere
- 1/9th the mass of the Earth
- cool most of the time

An inventory of our Solar System

Jupiter:

- Gas giant with no surface
- ultra thick atmosphere
- 318 times mass of Earth
- perhaps liquid water in atmosphere

An inventory of our Solar System

Saturn, Uranus, Neptune:

- Gas planets of various sizes.
- No solid surface
- thick atmosphere hides rocky core
- perhaps liquid water in atmosphere

An inventory of our Solar System

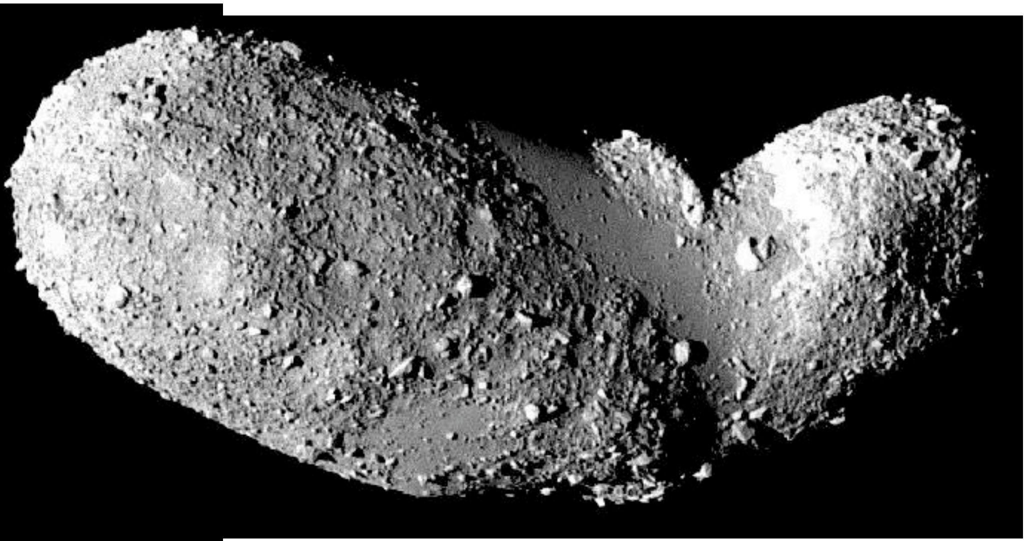
Pluto, Eris, and friends:

- icy surface
- extremely cold 30-50 Kelvin
- masses from 1/100 to 1/1000 Earth
- very far from Sun
- no liquid water

An inventory of our Solar System

Asteroids:

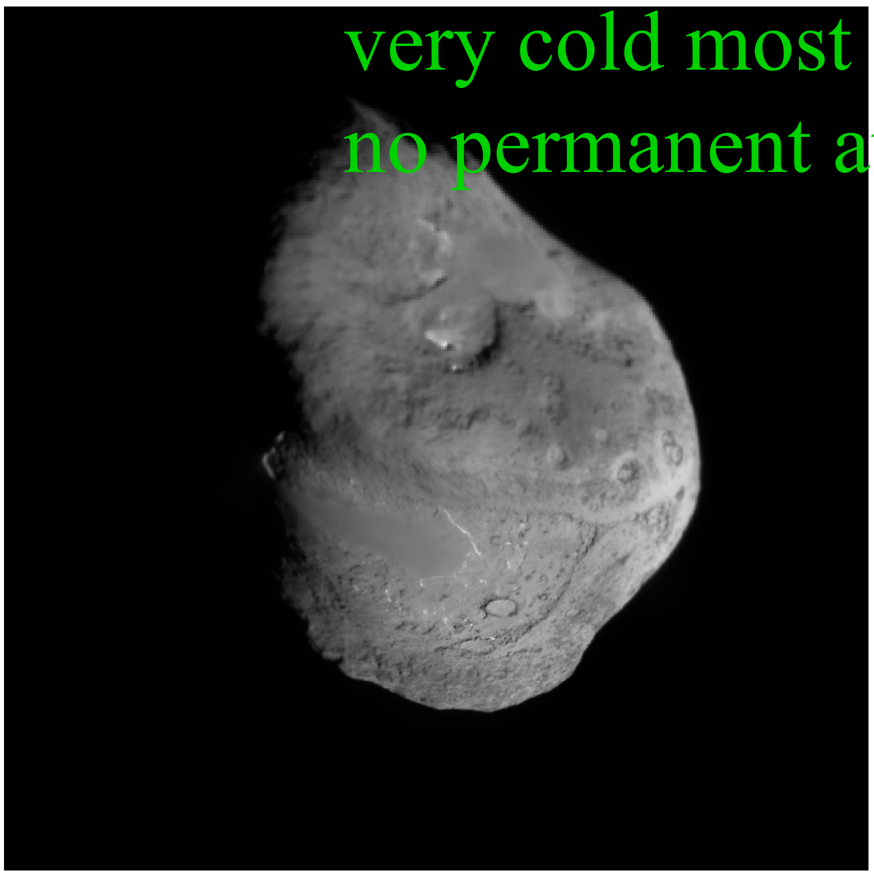
- rocky bodies
- resemble rubble piles
- very low mass
- no atmosphere

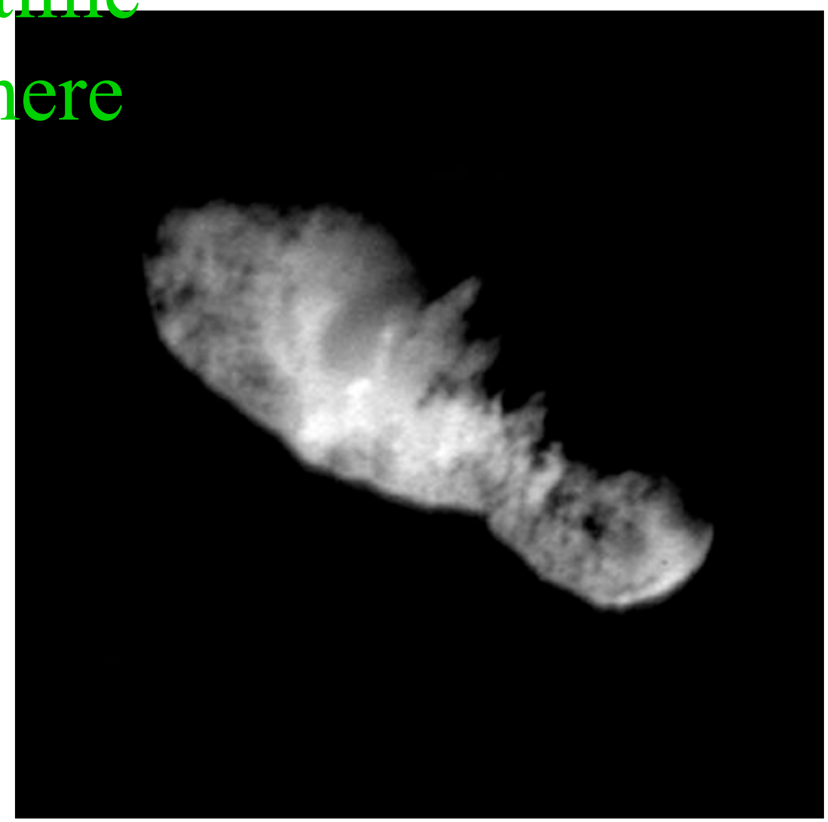


An inventory of our Solar System

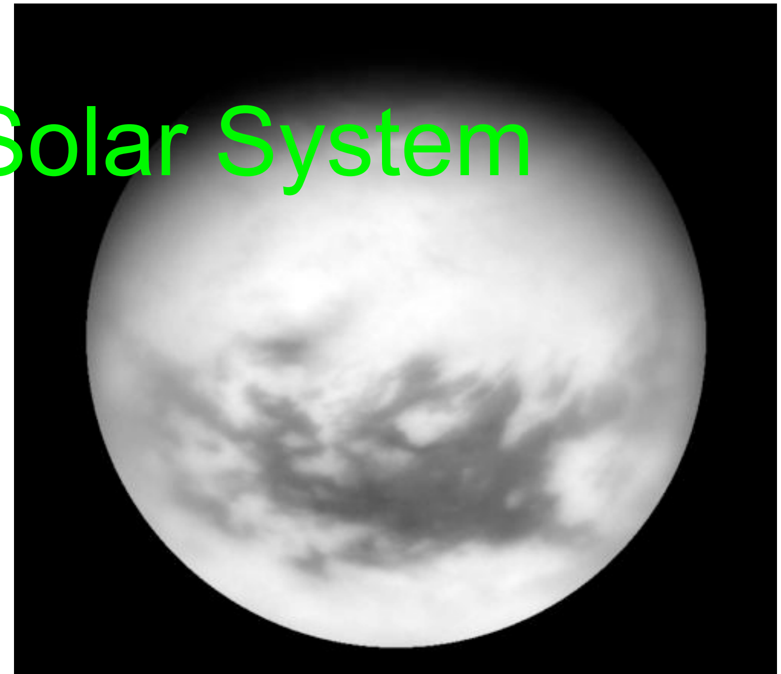
Comets:

- icy-rocky bodies
- rubble piles
- very cold most of the time
- no permanent atmosphere



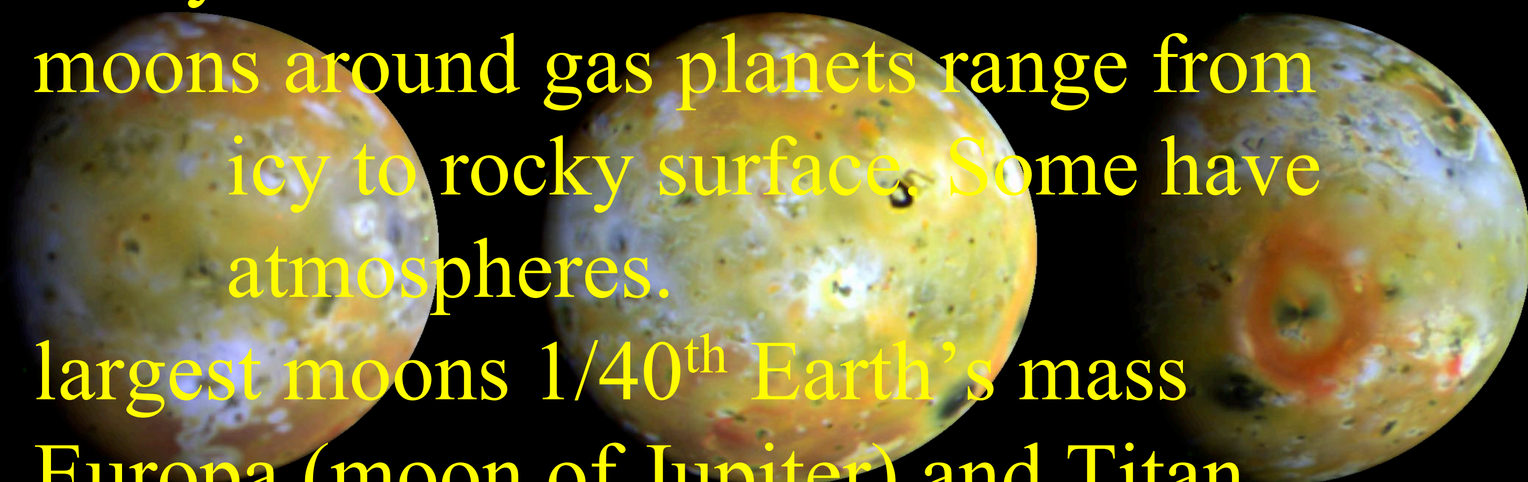


An inventory of our Solar System



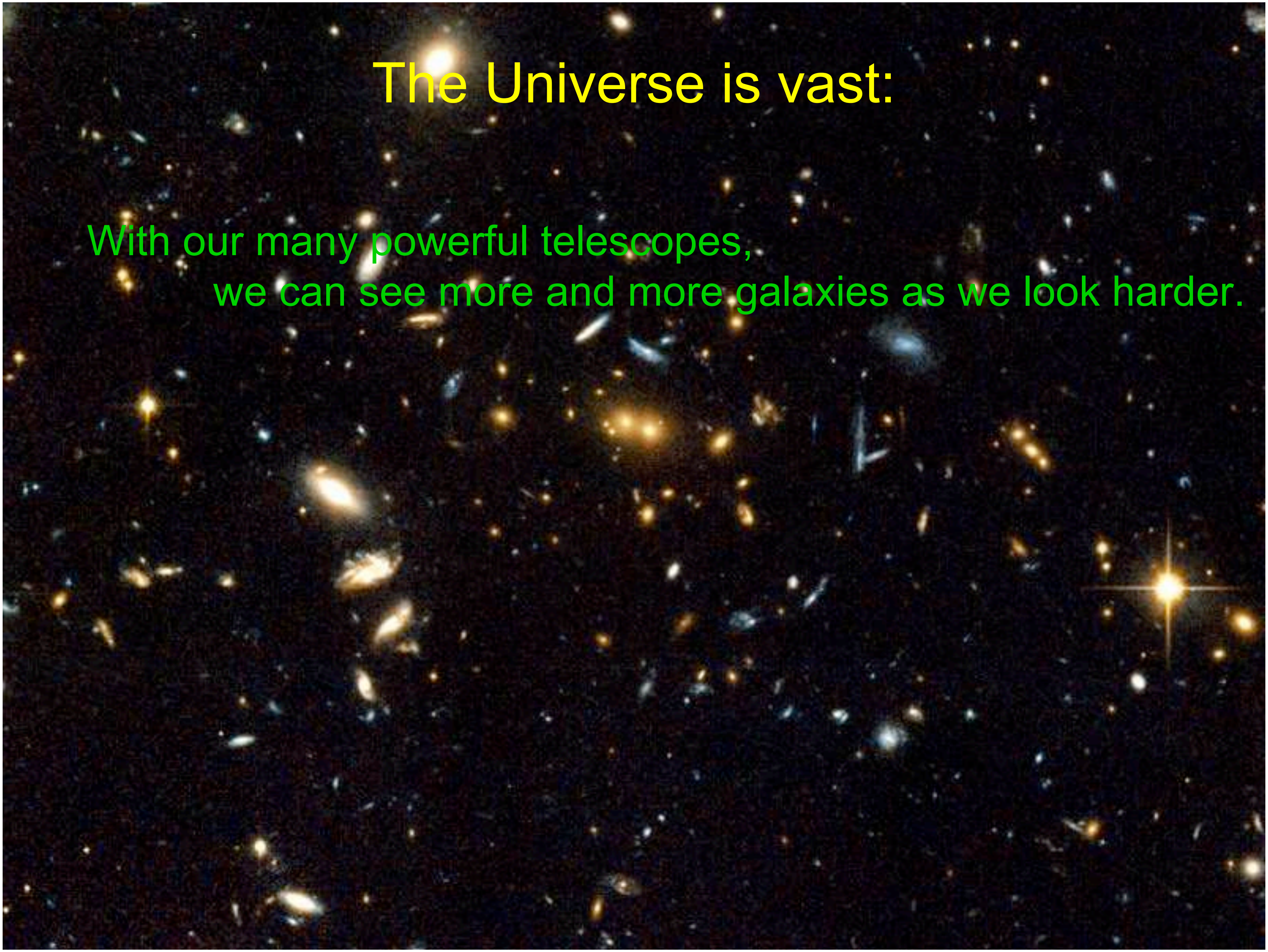
Moons of planets

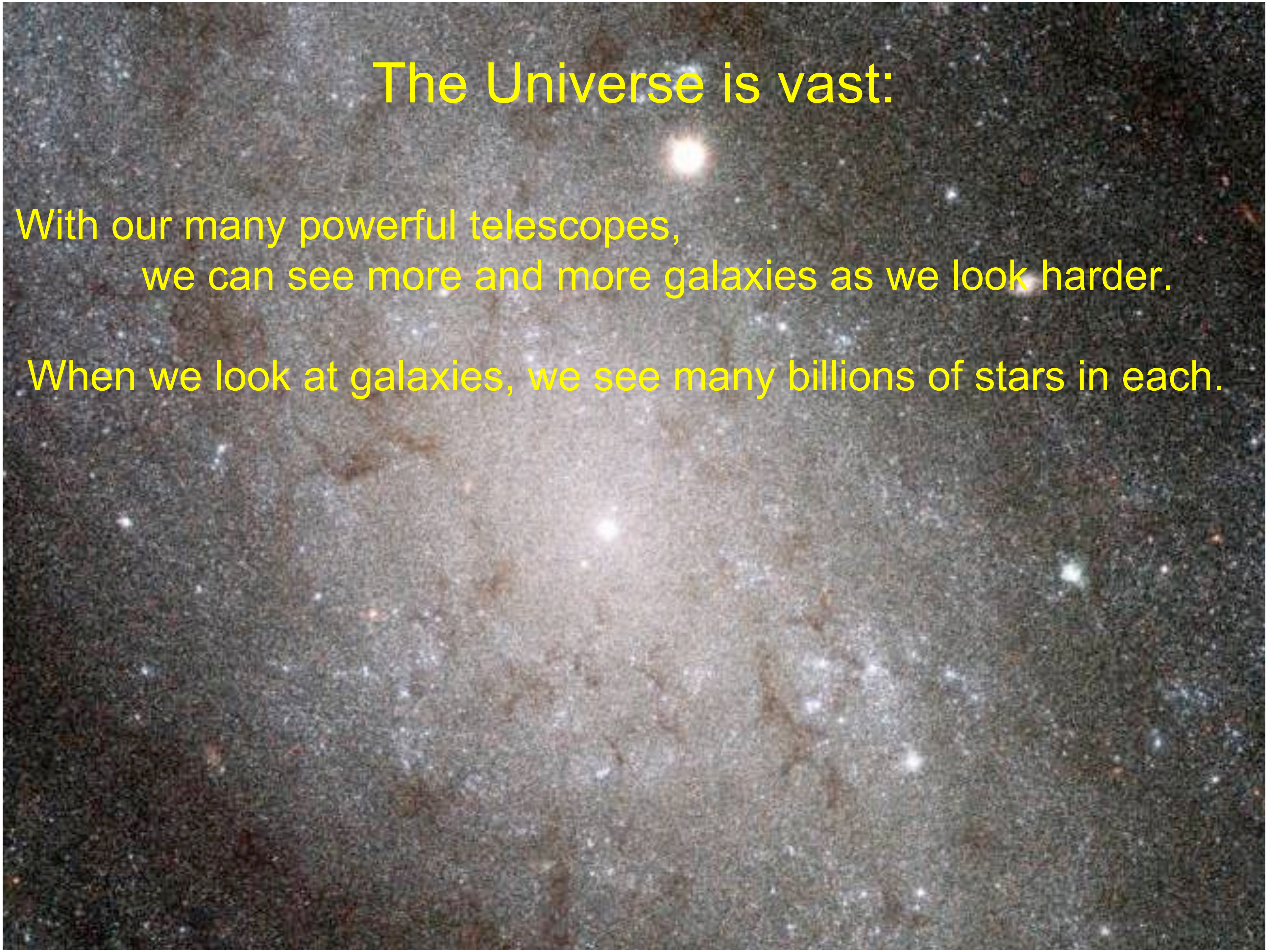
- rocky moons around terrestrials
- moons around gas planets range from icy to rocky surface. Some have atmospheres.
- largest moons 1/40th Earth's mass
- Europa (moon of Jupiter) and Titan (moon of Saturn) most interesting



The Universe is vast:

With our many powerful telescopes,
we can see more and more galaxies as we look harder.

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On average, there are 10 stars in each galaxy for each person on the Earth --- and there are billions of galaxies in the Universe.

Distances in Astronomy

The simplest way to think about distances in astronomy
Is in terms of light travel time.

Light travels about a foot in 1 billionth of a second.

Light travels from New York to LA in about 0.013 seconds.

Light travels from the Earth to the Sun in 8.3 minutes.

Light travels from the Sun to Neptune in 4.1 hours.
about 4 years to get to the nearest star.
about 25,000 years to the center of our Galaxy
about 2 Million years to the nearest big galaxy

Distances in Astronomy

The distances in our Solar System and Universe are quite daunting unless you assume that it is possible to

travel faster than the speed of light
travel through wormholes
or live for thousands of years

The first two appear physically impossible. The last one... well, let's let the biologists work on it!

What about our Galaxy?

It too is a big empty place… with lots of stars.

- Our galaxy contains about 200-400 Billion stars

- Most of those stars are lower mass and less luminous than our Sun.

- The Galaxy is about 30 kpc across… or 100,000 light-years across.

What about our Galaxy?

It too is a big empty place… with lots of stars.

If you scaled the galaxy down to fit into this room… so 100,000 light-years scaled to 50 feet.

then the Solar System out to Pluto would be about 20,000 atoms across.

the sun itself would be a little more than the size of an atom.

Consider this room filled with 300 billion bright little atoms.

There are roughly a billion times a billion more air molecules in this room…..

The Universe is vast:

Astronomers have developed a number of ways to measure the distance to galaxies:

- Cepheid variables
- Brightest stars
- supernovae

The distance to the nearest galaxies is around 1 Million parsecs (Mpc) = 3 Million light-years.

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The nearest big cluster is the Virgo cluster at 20 Mpc.

Extensive work has been done on galaxies out to 100’s of millions of parsecs

The Universe is vast:

How big is it in human terms?

If you scaled the Solar System to be 1 inch across….

the nearest galaxy would be 1/10th the way to the Moon

the Virgo cluster would be twice as far away as the Moon.

the Earth would be 1 millionth of an inch in diameter.

The Universe is mostly empty!

Galaxies occupy a small fraction of the volume of the Universe.

If our galaxy were scaled to the size of a frisbee:

the nearest normal galaxy would be about a frisbee about 10 feet away.

the Virgo cluster would a cluster of 1000’s of frisbees with a diameter of about 40 feet located 200 feet away.

In between the galaxies is gas of a few thousand atoms per cubic meter. Barely enough to make a few interesting molecules.

The Universe is old:

How do we know that it is old?

- radioactive dating of rocks on the Earth
- radioactive dating of meteorites
- dating of star clusters based on H-R Diagram
- dating of individual stars based on abundances of elements and stellar evolution models
- mapping of variations in the cosmic background radiation from the formation of the Universe.

The Universe is old:

So how old is it?

radioactive dating of rocks on the Earth and meteorites

the Solar System is about 4.5 Billion years old.

dating of star clusters and individual stars

the Universe is at least 10 Billion years old

mapping of variations in the cosmic background radiation from the formation of the Universe.

The Universe is 13.7 Billion years old, plus or minus 200 Million years. 9 Billion years older than the Earth

Time is expansive in the Universe

The Universe formed 13.7 Billion years ago.

The Earth and Solar System formed 4.6 Billion years ago.

The dinosaurs ruled the Earth 65-220 million years ago.

Humans got started about 1 million years ago.

Recorded history started 5000-6000 years ago.

Electricity was harnessed for human use 250 years ago

Space travel started about 50 years ago

Time is expansive in the Universe

If we reduce all of cosmic history to date to 1 calendar year…

then the first stars in our galaxy formed in February
our Sun formed in early September
the dinosaur extinction occurred on December 30
human agriculture started with 25 seconds left in the year
space travel began with 0.1 seconds left in the year!

That the human race is today at this exact point of development is an accident of our Sun's birth and the details of evolution on Earth.

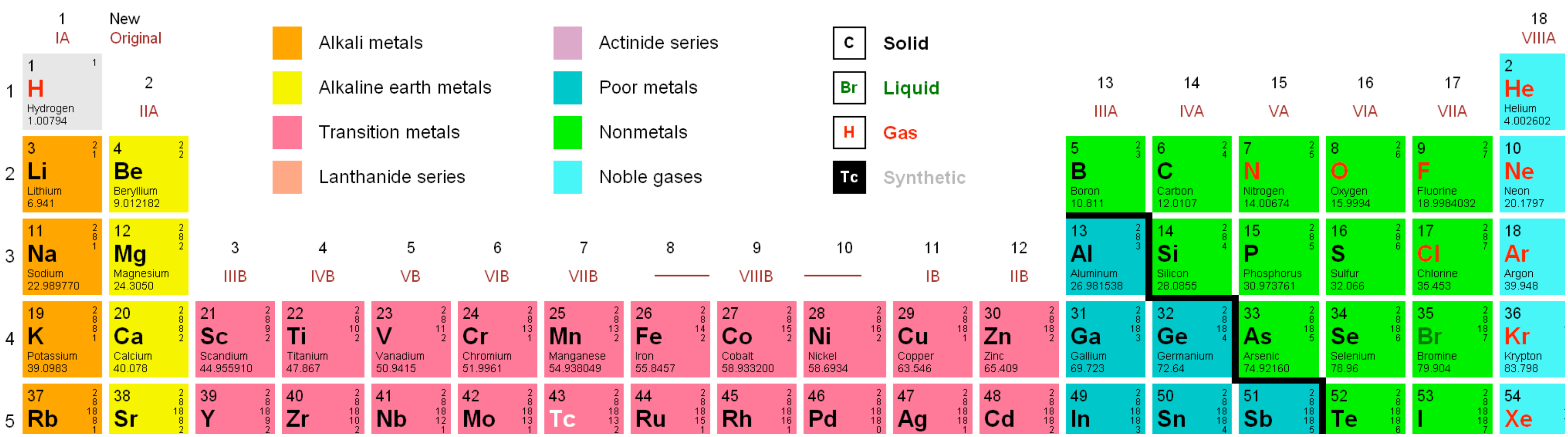
The elements for life are wide-spread.

Life requires elements beyond Hydrogen and Helium….

Helium does not form molecules – leaving Hydrogen to form only H_2.

Earth life requires Hydrogen, Carbon, Nitrogen, Oxygen, calcium, and a good number of other elements.

Are they present throughout the Universe?



The elements for life are wide-spread.

We can measure the abundances of the basic elements in stars throughout our galaxy.

Abundances in the galaxy are similar to our Solar System.

We can measure abundances in other nearby galaxies.

Many have abundances similar to our galaxy

We can measure abundances in gas in very distant galaxy clusters.

The Universe formed the basic elements needed for life very early… 10-12 Billion years ago.

The elements for life are wide-spread.

Where are these atoms of Carbon, Nitrogen, Oxygen created?

They were not there in significant abundance at the birth of the Universe.

These atoms are created in the later stages of the life of a star at its core.

When some stars die, they explode or have winds that carry these elements back out into the Universe.

We are made of atoms created in the center of stars in the early universe!

Our physical laws appear universal

We have no direct evidence to support changes
in physical laws at different positions or times.

How would we know?

By looking at the relative wavelengths of different atomic lines in distant galaxies we find that the physical constants that determine atomic structure have not changed

By seeing that the same physical laws can explain observed phenomena in our galaxy, nearby galaxies, and distant galaxies, Ockham’s Razor dictates that the laws are unchanged.

Summary

- The universe is really, really big!
  Also extraordinarily old
- Many potential spots for life...
  ...but currently we only know of one
- How do we get planets and the right elements for life? Stay tuned...