ASTR 380

The Universe: the context for Life

A THREE LETTER ABBREVIATION FOR AN UNIDENTIFIED FLYING OBJECT?

HMM? UHH... ...... PASS!
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!
The Universe is vast:

With powerful telescopes like the Hubble Space Telescope, we can see more and more galaxies as we look harder.
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An average, this are 10 stars in each galaxy for each person on the Earth --- and there are billions of galaxies in the Universe.
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.
The Universe is vast:

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

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 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 Billions years old, plus or minus 200 Million years. 9 Billion years older than the 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 H2.

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 that the relative wavelengths of different atomic lines in distant galaxies we determine 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, Occum's Razor dictates that the laws are unchanged.
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.
What about our Galaxy?

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

- Our galaxy contains about 100 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 100 Billion bright little atoms.

There are roughly a billion times a billion more air
molecules in this room…..
What about our Solar System?

It’s a little more comfortable…

If we scaled the sun to be the size of a big beach ball… Say 1 meter across….

Then the Earth would be about 1 cm across and located about 100 meters away.

Jupiter would be 11 cm in diameter and located about 500 meters away.

Neptune would be about 4 cm at a distance of 3 km.
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 1.3 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 near star.

about 25,000 year to the center of our Galaxy

about 2 Million years to the nearest 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 worm-holes, or live for 1,000s of years.

None of which appear physically possible.
Time is also expansive in the Universe

The Universe formed 13.7 Billions years ago.
The Earth and Solar System formed 4.6 Billion years ago.
The dinosaurs ruled the Earth 100 million years ago.
Humans got started about 1 million years ago.
Recorded history started 4000-5000 years ago.
Electricity was harnessed for human use 250 years ago
Space travel started nearly 50 years ago
Time is also 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.
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
- $1/9^{th}$ the mass of the Earth
- cool most of the time
Jupiter:

- Gas giant with no surface
- Ultra thick atmosphere
- 318 times mass of Earth
- Perhaps liquid water in atmosphere
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 Kelvins
- masses from 1/100 to 1/1000 Earth
- very far from Sun
- no liquid water
An inventory of our Solar System

Asteriods:
- 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
Moons of planets

Moons around terrestrial planets are rocky, while moons around gas planets can have icy to rocky surfaces and some have atmospheres.

The largest moons are about 1/40th the mass of Earth. Titan, the moon of Saturn, is the most interesting because...
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....