Life in the Universe

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What Is This Presentation About?

Life in the Universe

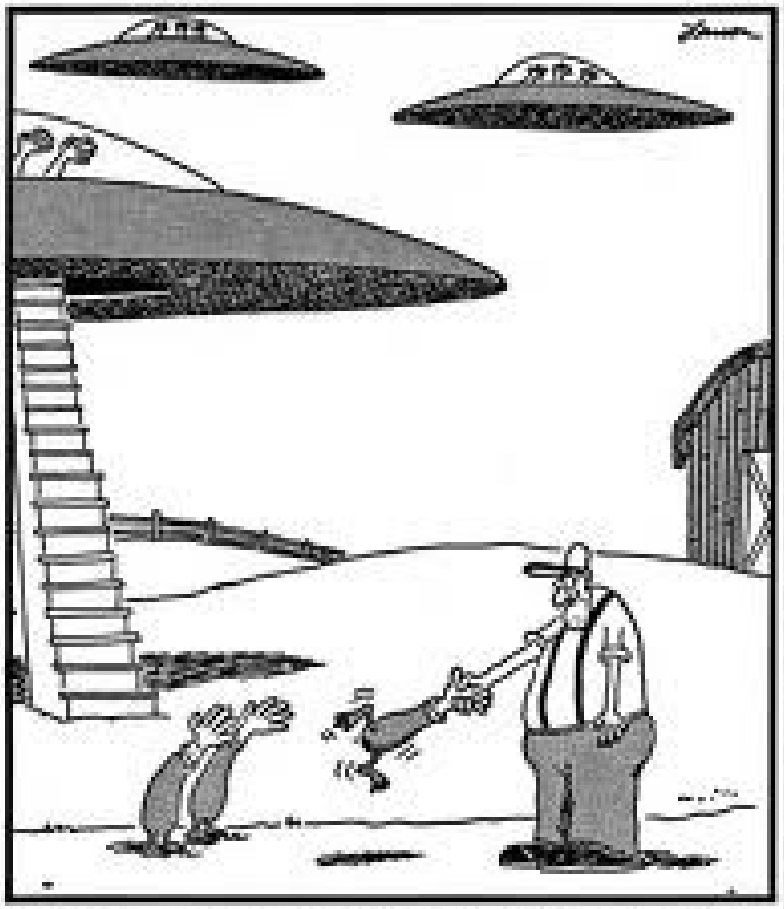
NASA

- There are tens of billions of galaxies, each with hundreds of billions of stars like the sun, many with planets like those in the solar system. Is there life out there?
- Is it primitive, or like us, or more advanced?
- How could we discover and study it, and perhaps make contact with it?

Outline

- Introduction: extraterrestrial life in science and in popular culture
- What is life?
- Life on Earth
- The origin of life on Earth
- Life in the solar system?
- Life beyond the solar system?

Why This Topic is Interesting/Relevant



Inadvertently, Roy dooms the entire earth to annihilation when, in an attempt to be friendly, he seizes their leader by the head and shakes vigorously.

- Exciting!
- Interdisciplinary
- Open to scientific investigation
- Relevant to the origin and future of life on earth
- Extraterrestrials are part of popular culture!

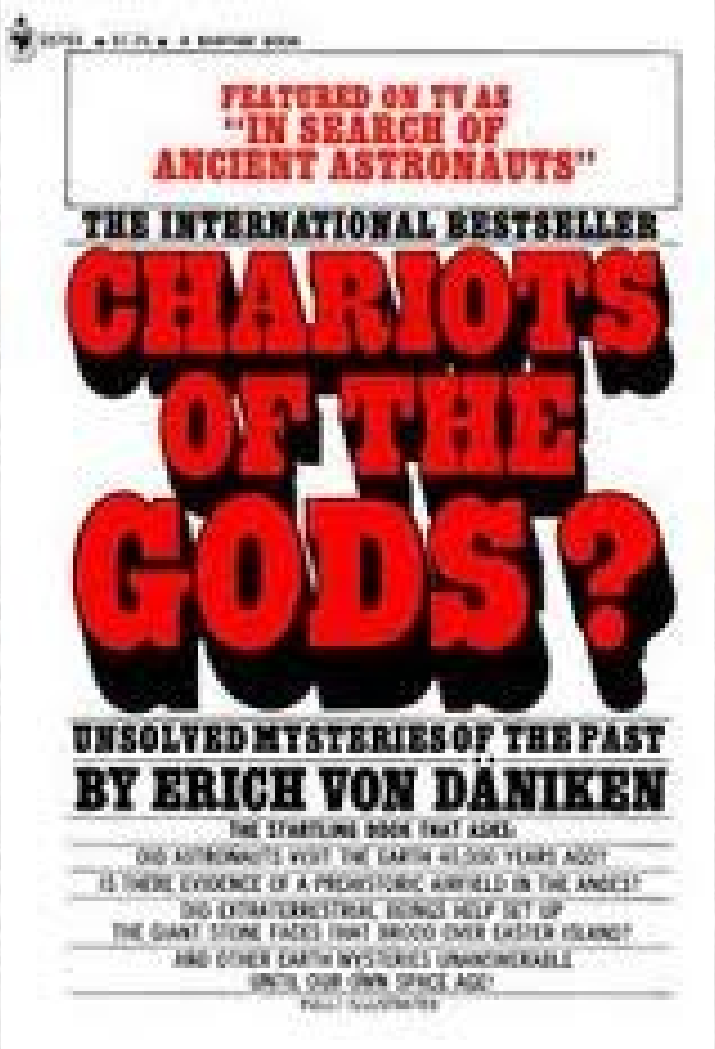
Extraterrestrial Life in Science and Popular Culture

Aliens in Popular Culture
UFOs and “Flying Saucers”

Sony Pictures

- Unidentified Flying Objects (UFOs) have been observed since the beginning of the Cold War in daytime and as lights in the night-time sky
- Contrary to popular belief, there is no evidence that they are extraterrestrial; there are a variety of simple, mundane explanations

“Ancient Astronauts?”



Econ-Verlag/Putnam

- Erich von Daniken, a convicted embezzler and fraud, and an accused plagiarizer, produced breathless, pseudoscientific claims of ancient space aliens ...
- ... for which there was/is no evidence

Scientific Search for Extraterrestrial Life

- Over one-third of Americans believe that space aliens have landed on Earth
- There is no evidence that this is true
- The scientific search for extraterrestrial life is based on evidence and critical thinking, and is equally exciting!
- Psychological question: why are pseudoscientific views so widely held?

The Nature of Life

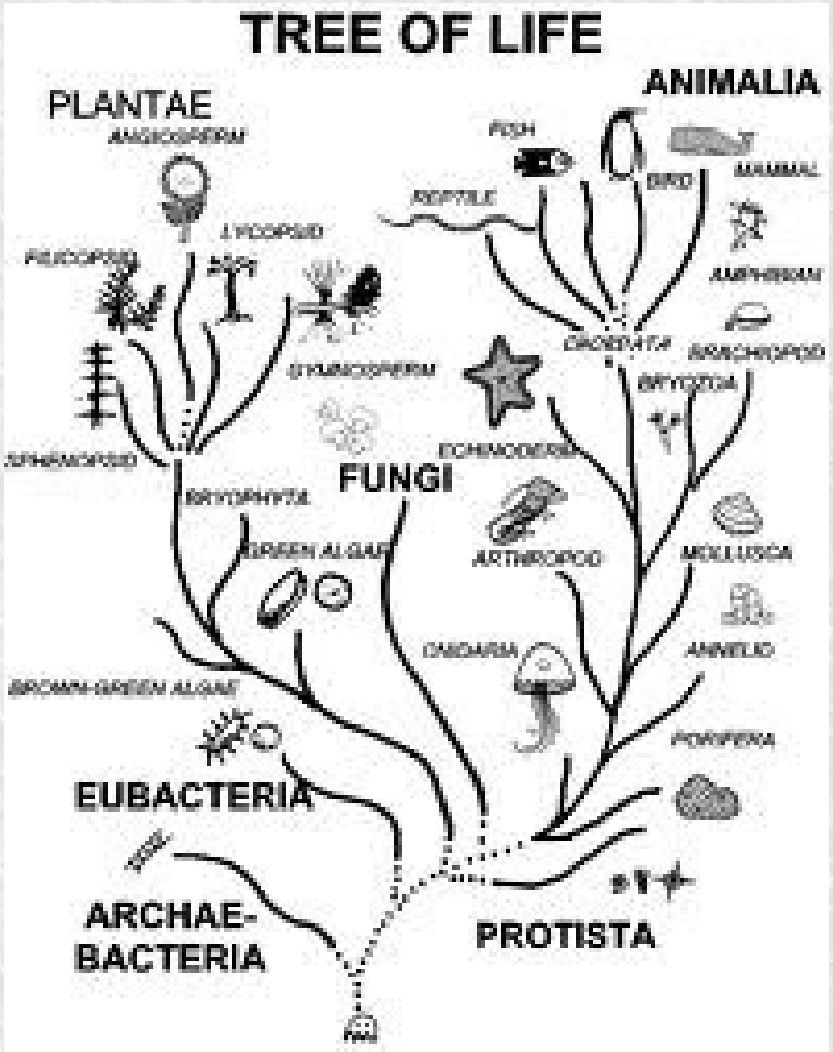
Life on Earth

"life as we know it"

NASA

- Life on earth ranges from the simplest one-celled organism, to "intelligent" us
- Most life on earth is simple, like bacteria
- But simple life has evolved for billions of years; the first life would have been much simpler

The Tree of Life



- It is possible, in several ways, to construct an outline of how species are related (they are all our “cousins”), and presumably how they evolved in time
- But remember that today's existing organisms have been evolving for billions of years

What is Life?

- Life on earth is based on series of chemical reactions, involving organic (bio)molecules in aqueous solution, with the input of energy, resulting in increased complexity – reproduction and evolution. Life is ...
- Carbon-based
- Water-based
- Driven by energy
- Characterized by reproduction and evolution

Extremophiles – Extreme Life
not just a “warm little pond”

Wikipedia

- Although most life on earth exists in moderate environments, there are extremophiles which flourish in extreme environments:
- Hot and cold, acid and alkaline, dark and light, dry ...
- So the “boundaries” of life, as we know it, are being extended

The Sun – Life's Essential Star

NASA

- The sun – 99.8% of the material in the solar system
- Its gravity holds the solar system together
- Its energy (produced by nuclear fusion) has nourished life on earth for 4 billion years

Origins

You Are Starstuff!

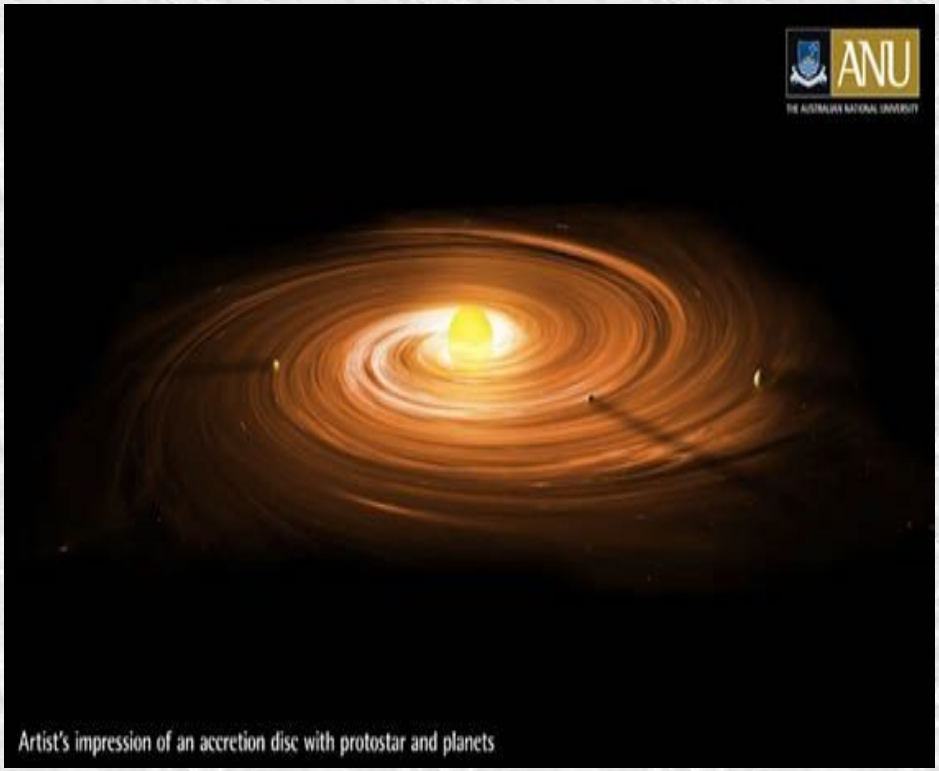
NASA/ESA/HST

- Atoms are made by nuclear reactions in stars (except hydrogen and most helium -- made in the birth of the universe)
- Rare massive stars explode as supernovas, spewing heavier elements into space
- They join with other recycled elements in nebulas where new stars are born

The Beautiful Orion Nebula
Visible Birthplace of New Stars and Planets

NASA

The Formation of Stars and Planets



- Part of a nebula contracts due to gravity
- It spins more rapidly (due to “the figure skater effect”) and forms a disc
- The sun forms in the denser centre; the planets form in the surrounding disc

The Young Earth: The Hadean Era

- For the first 500 million years of earth history, it was bombarded with left-over rocky and icy debris
- This brought energy (therefore heating), and matter (including the elements of life)...
- Including water, from the icy material

Carbonaceous Chondrites
Natural organic matter from space

Allende Meteorite; wordpress.com

- These are primitive leftovers from the origin of the solar system
- They contain about 6% carbon, much of it complex organic molecules e.g. amino acids
- Complex molecules form naturally and easily
- Some of these molecules would have fallen to earth

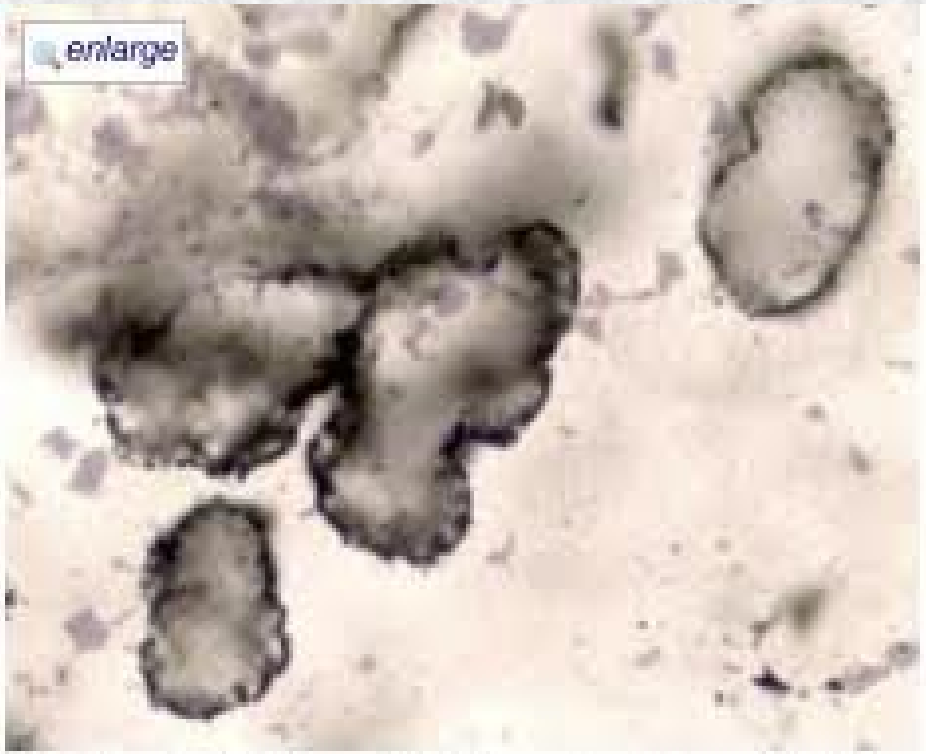
The Miller-Urey Experiment

Forming complex molecules here on earth

Stanley Miller: wikipedia

- Stanley Miller and Harold Urey applied energy (a spark) to a mixture of simple gases which would have been in the earth's original atmosphere.
- After several days, a mixture of complex organic molecules (e.g. amino acids) had been formed – the building blocks of life

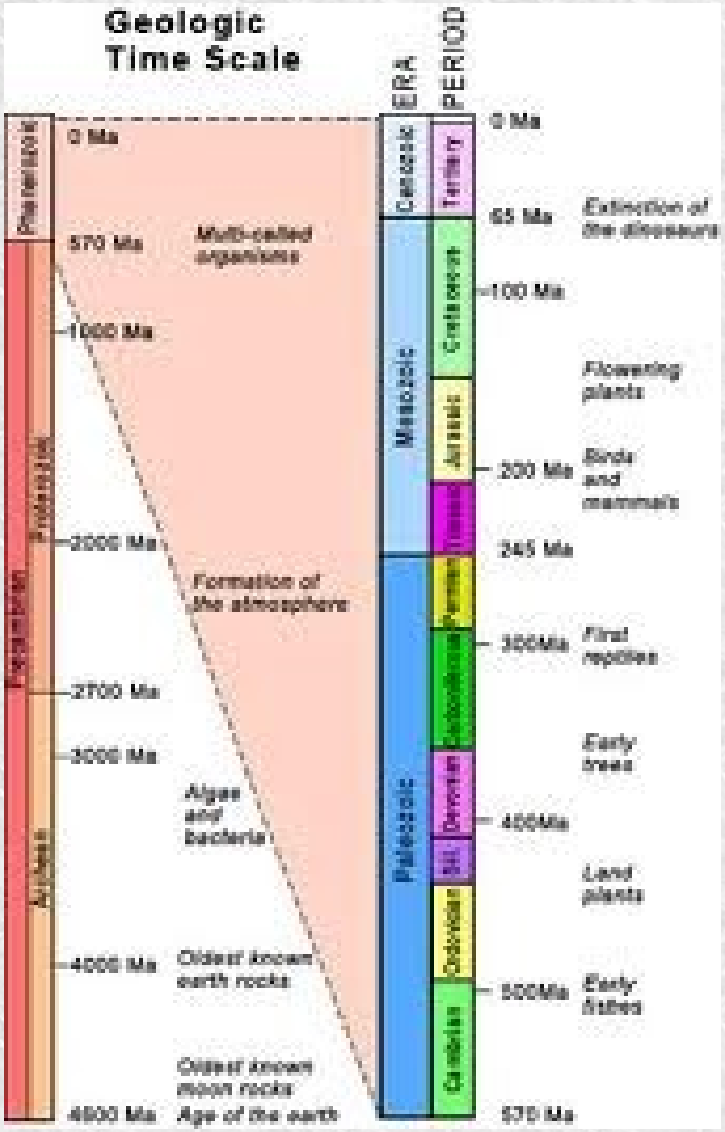
The Oldest Fossils



Fossilized cells from 3.4 billion years ago. (Credit: David Wacey)

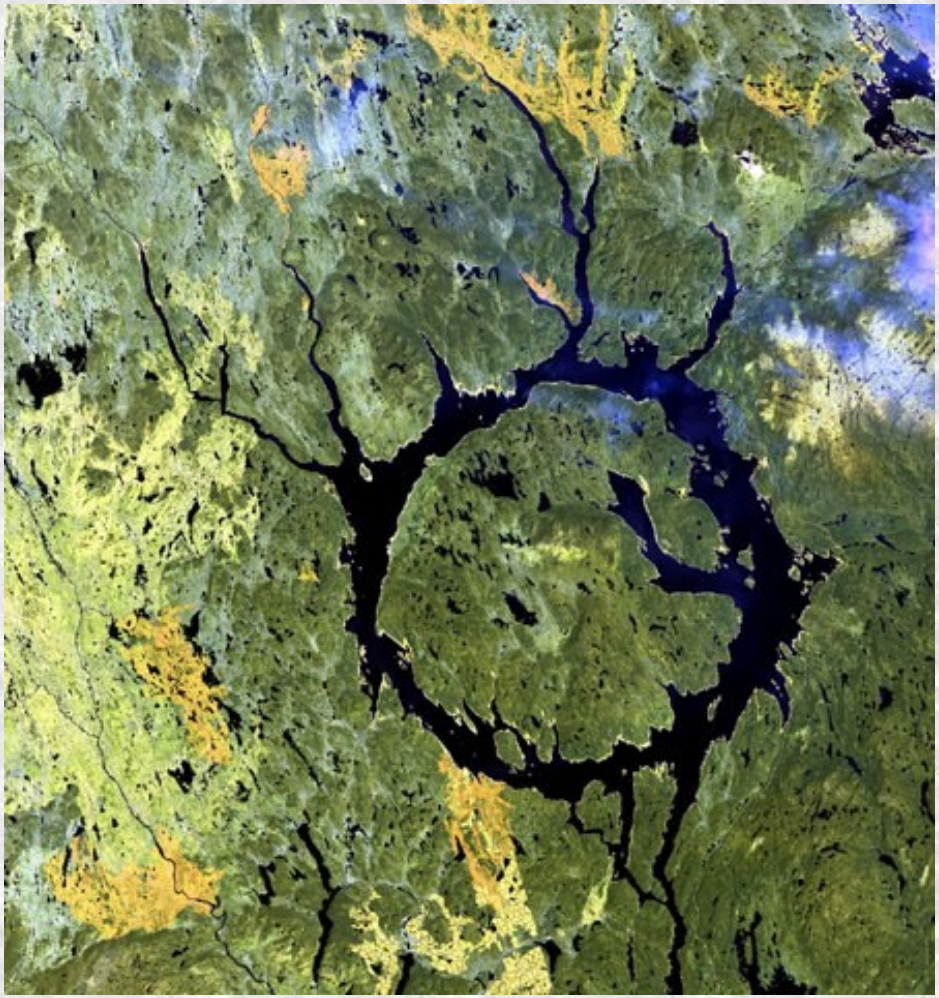
- The oldest fossils – of one-celled organisms -- date from about 3.5 billion years ago
- Older organisms would have been even simpler and more fragile, and unlikely to be preserved

The Geological Eras



- In the fossil record, we can follow the development of life, from simple one-celled organisms, to human beings
- In the last billion years, there are also records of several major extinctions

Extinctions

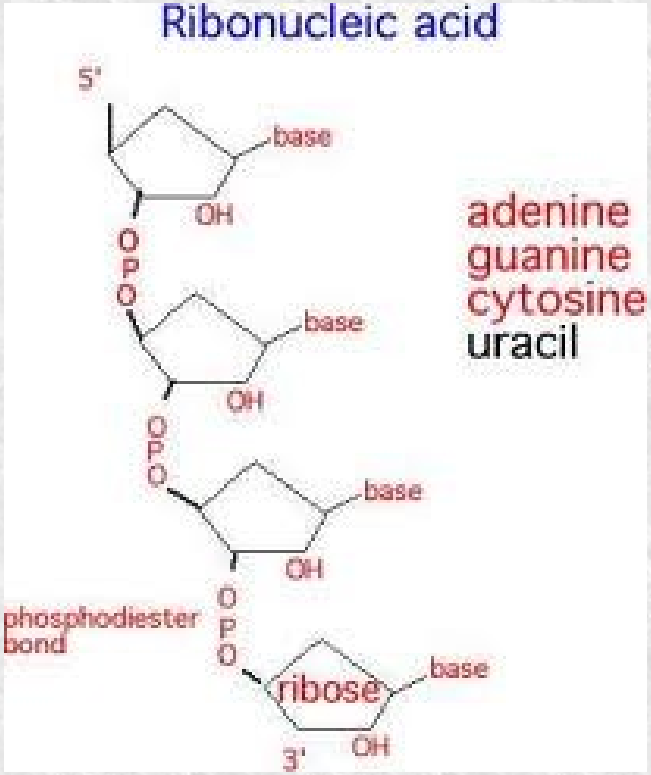


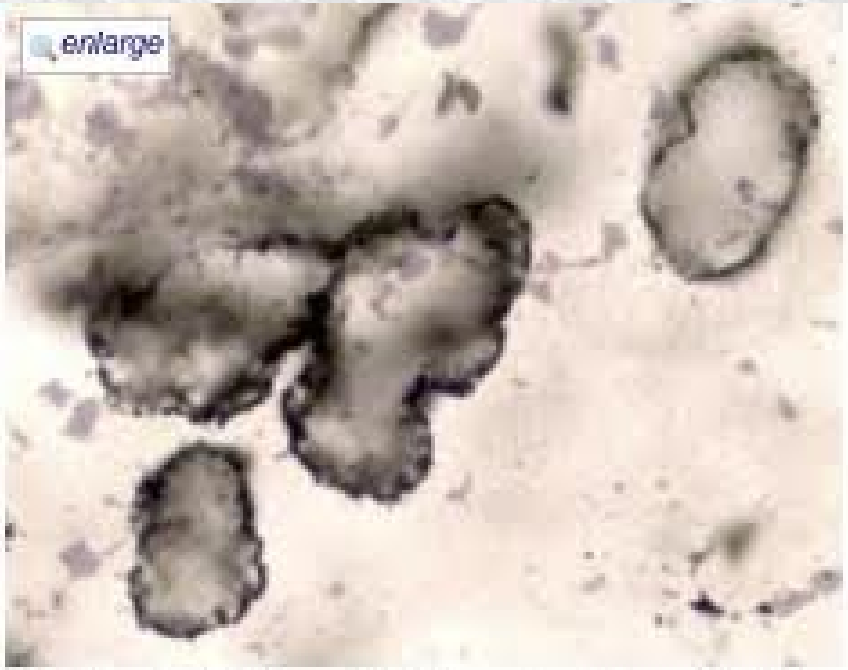
Manicouwagan Crater; NASA

- Many of the extinctions which mark the ends of geological eras may have been due to impacts of asteroids or comets, devastating the biosphere and leaving impact craters behind (like Manicouwagan Crater at left)

How to Bridge from Complex Molecules to Simple Cells?

A problem not yet solved!





Fossilized cells from 3.4 billion years ago. (Credit: David Wacey)

Life Elsewhere in the Solar System?

The Universality of the Laws of Science

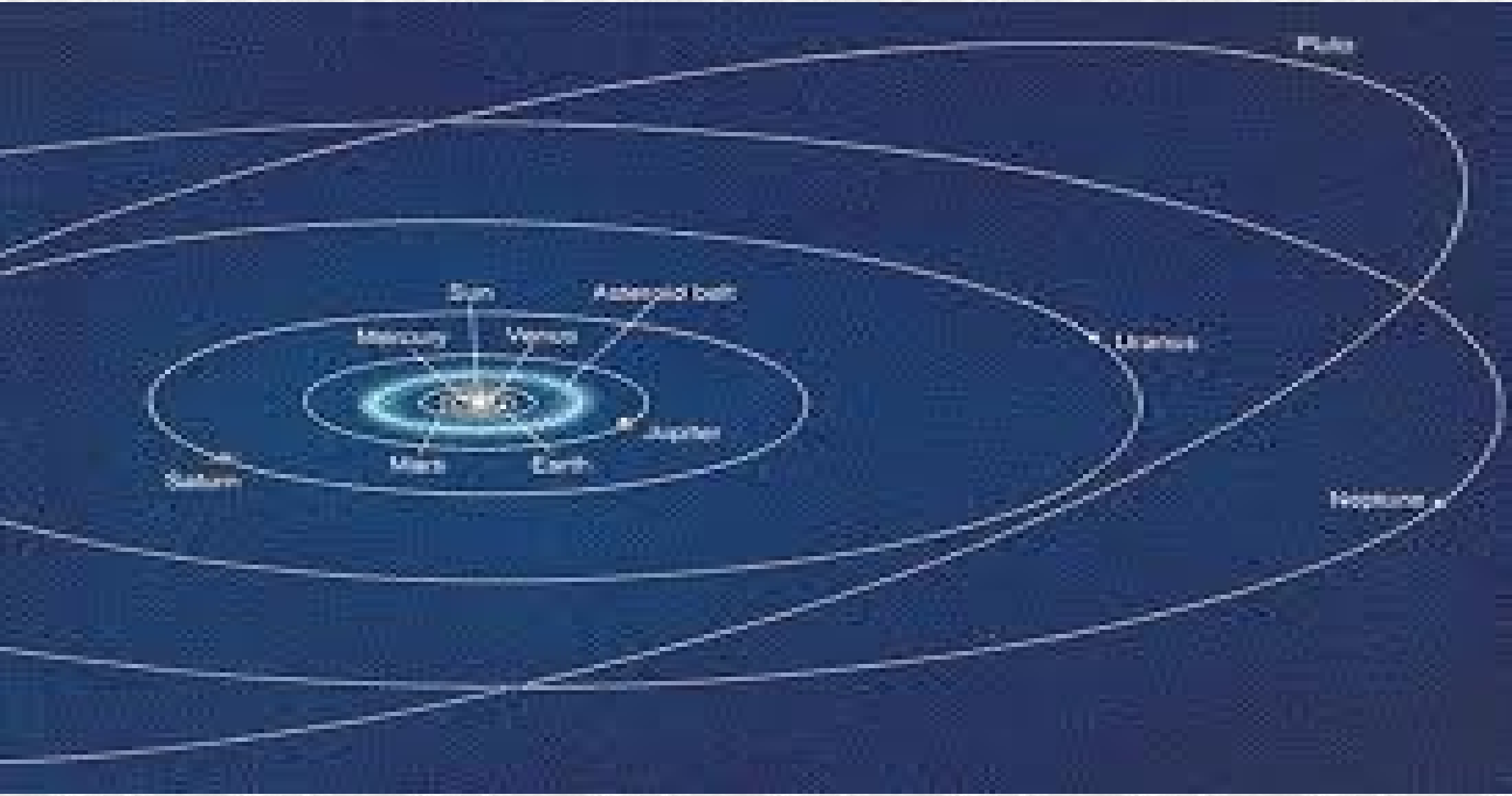
an essential consideration!

NASA/ESA/HST

- This image shows galaxies, billions of light years away, seen billions of years ago
- They are made of the same material, obeying the same laws of physics that we find on Earth, and in the solar system
- The laws of physics are constant in time and space

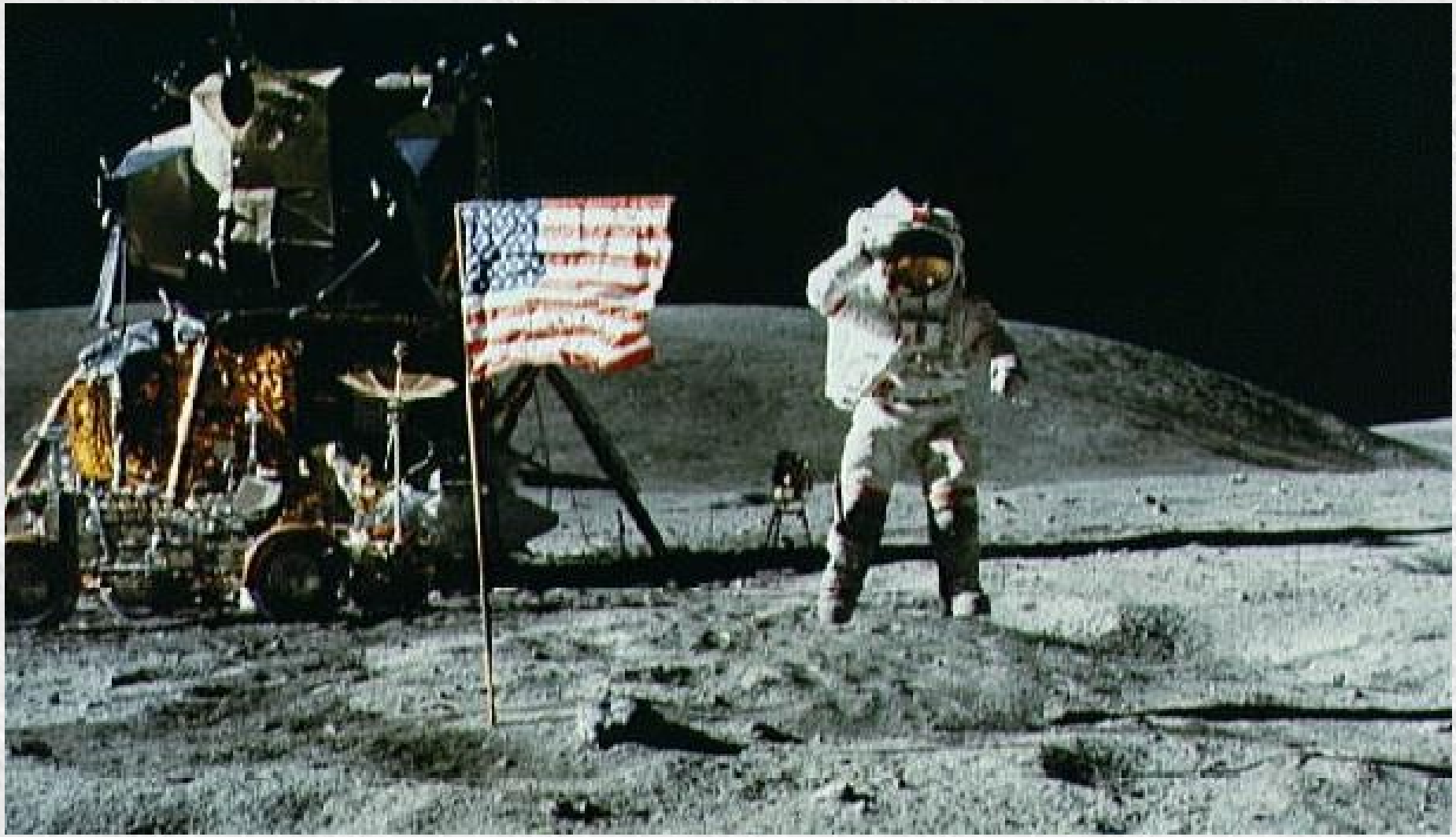
The Solar System

6,000,000,000 km from the sun to its edge



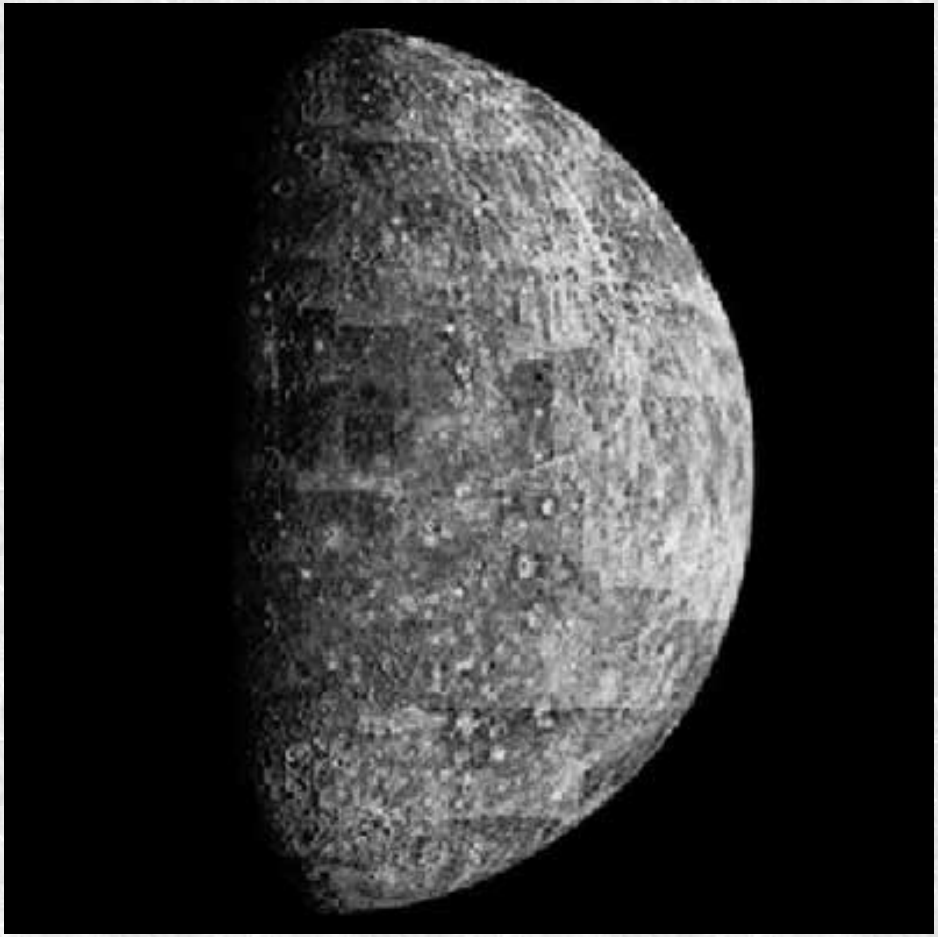
Humans on the Moon, 1969+

The moon -- no air, no water, no life



NASA

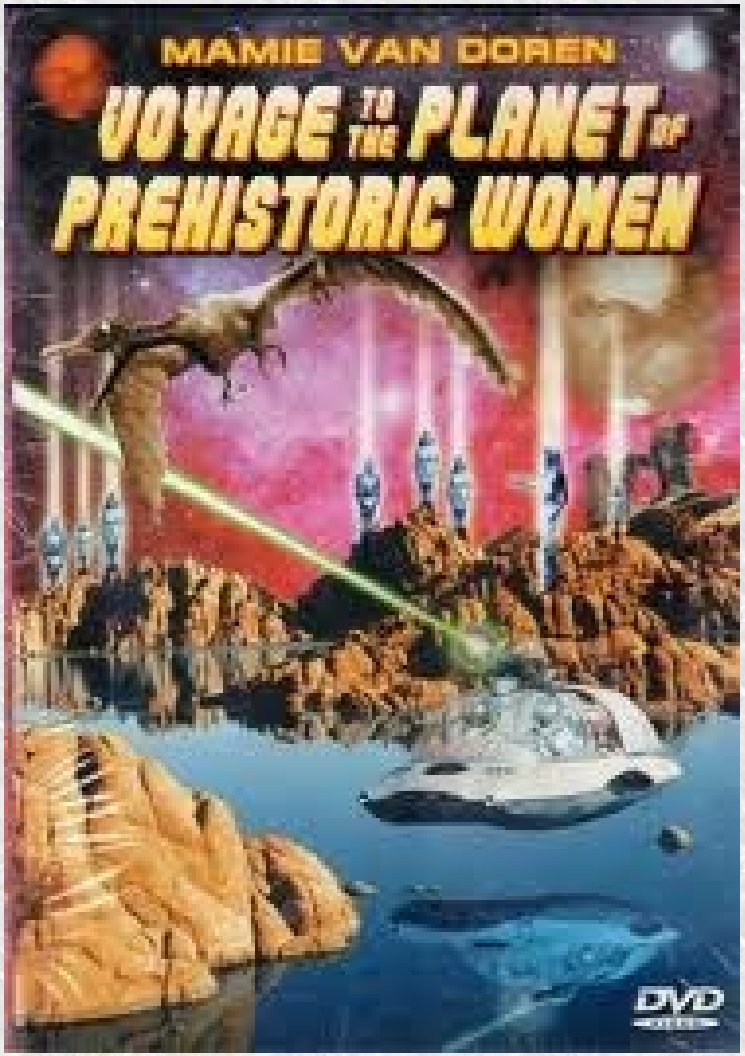
Mercury



NASA

- Mercury, like the moon, is airless and waterless, though there may be ice frozen in shadowed craters near the poles
- Extreme range in temperature

Venus in Science Fiction and Reality



Public domain

- Venus is similar to earth in size and mass
- Being closer to the sun, it was expected to be warmer – jungles or deserts?
- In fact, the greenhouse effect has caused extreme atmospheric temperature (450C) and pressure (90 x Earth)
- Venus is uninhabitable!

Mars

NASA

- Day/night and seasons like Earth
- Thin, cold, clear atmosphere
- Rusty deserts, polar caps of “dry ice” and some water ice
- The planet most like Earth!

The “Canals” of Mars

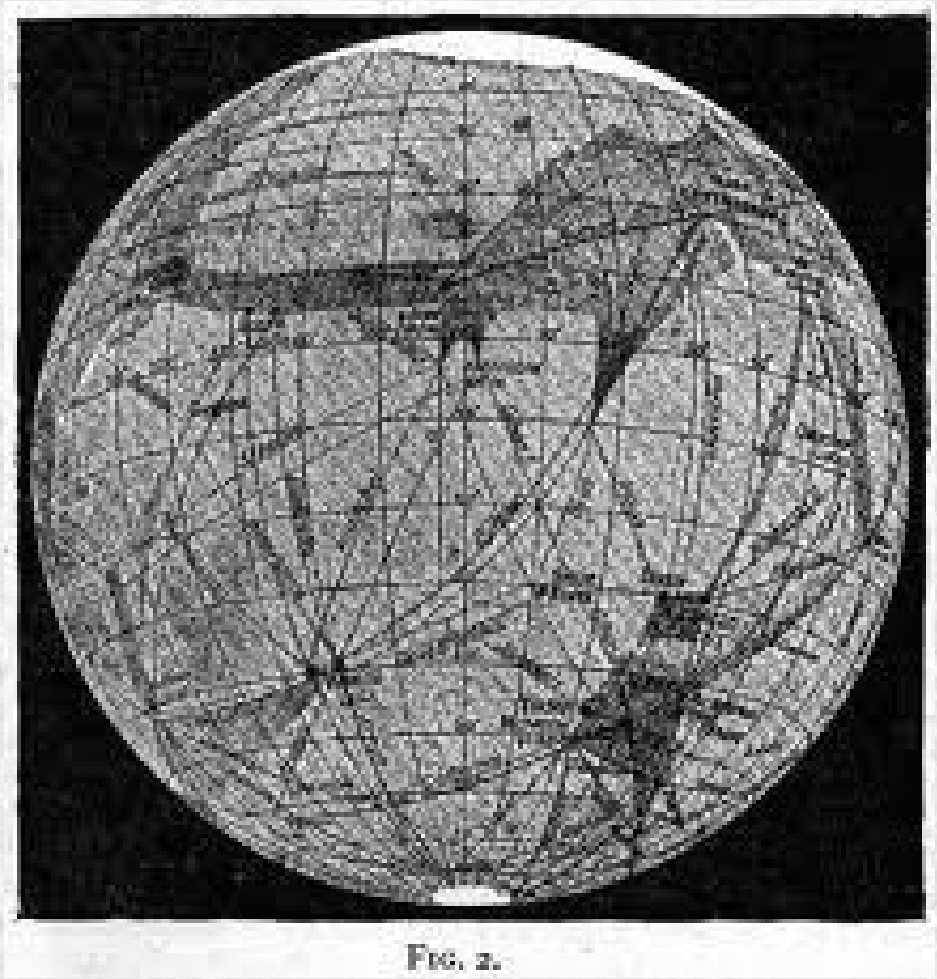
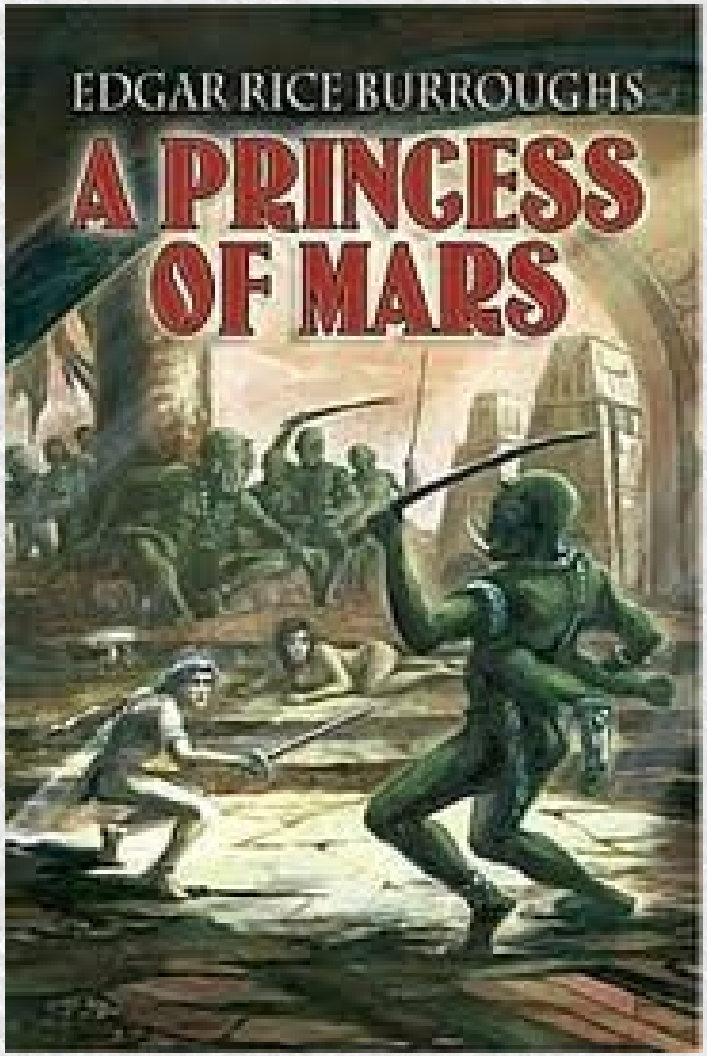


Fig. 2.

Percival Lowell

- 19th-century Italian astronomers observed – by eye -- linear features on the planet; canali = channels
- This was mistranslated as canals, and they were assumed to be artificial
- They were an optical illusion – but led to today's science fiction!

Mars in Science Fiction



Dover Books

- Mars' similarity to Earth, plus the “canals”, suggested that Mars might be inhabited
- Widespread belief in Martians!
- The “inhabitants” are usually portrayed as hostile, maybe because Mars was the god of war

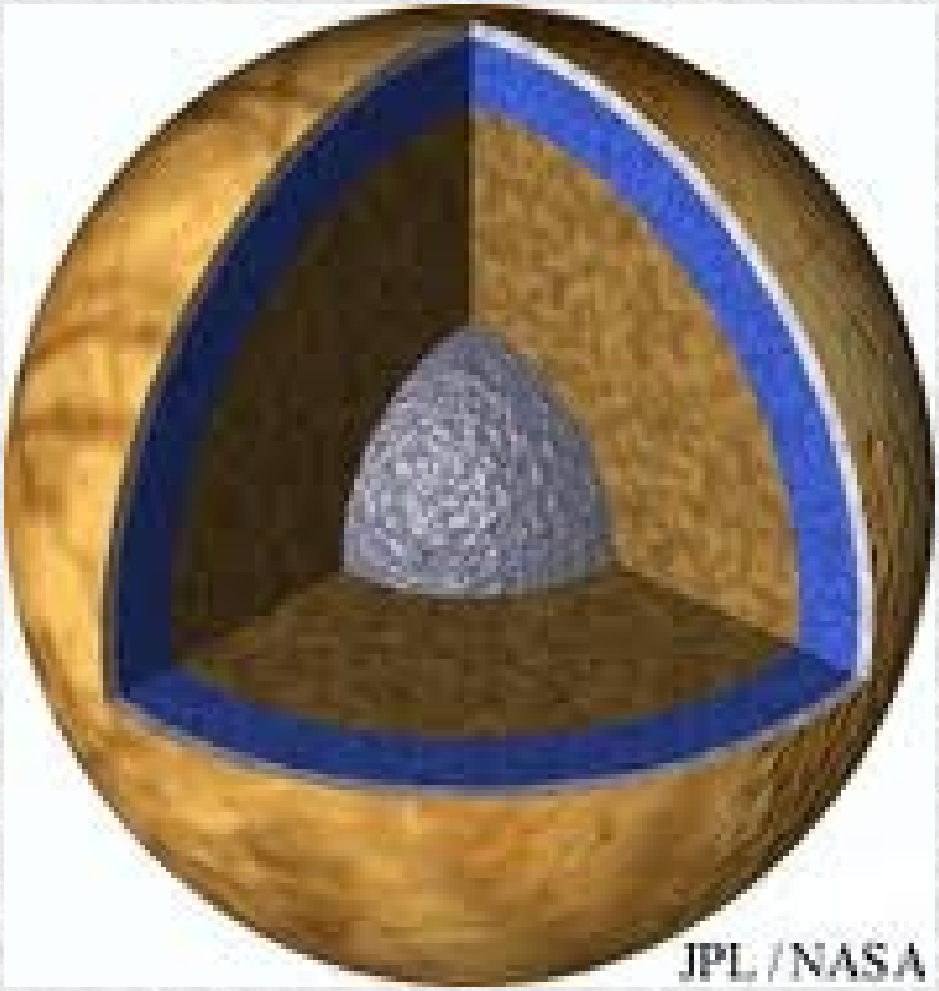
Mars in Reality

NASA

- Mars' atmosphere is too cold and thin for water (or life) to thrive
- But four billion years ago, Mars was warm and wet!
- Simple life may have formed then
- Mars landers are searching for evidence

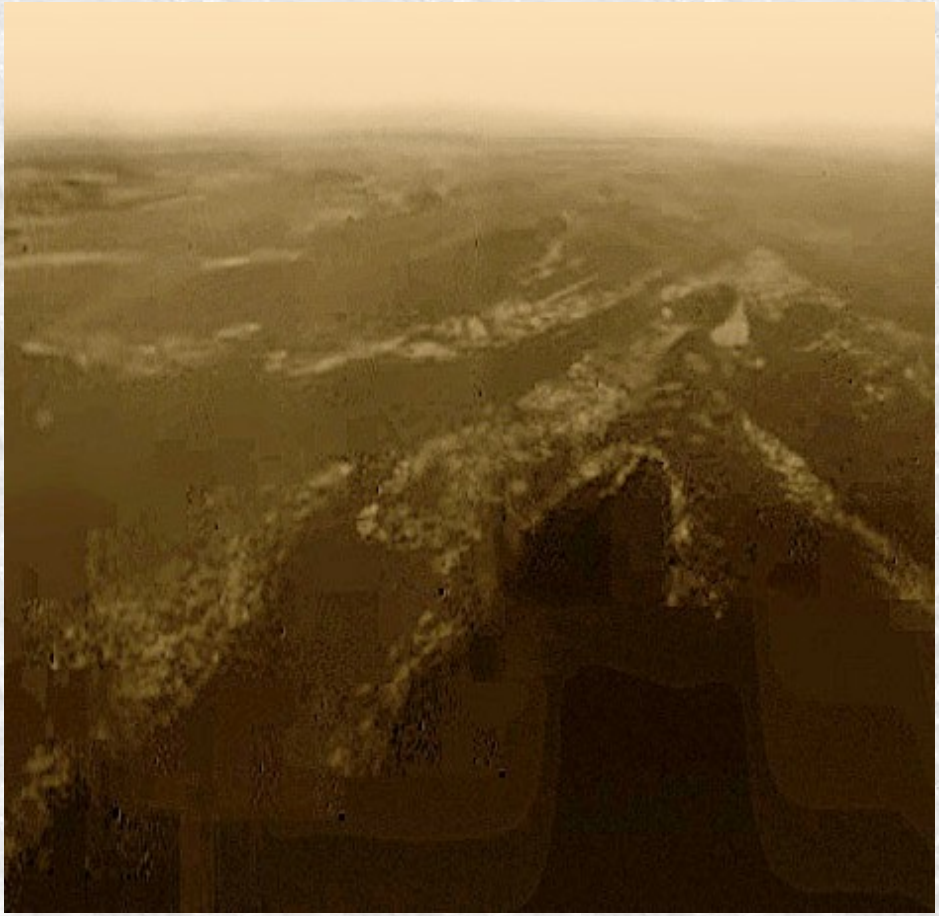
Europa: A Large Moon of Jupiter

Moons are possible abodes for simple life



- Europa, the second of the Galilean moons of Jupiter, has deep subsurface oceans
- There are thermal energy sources, water, and probably some organic molecules
- Life might have begun there

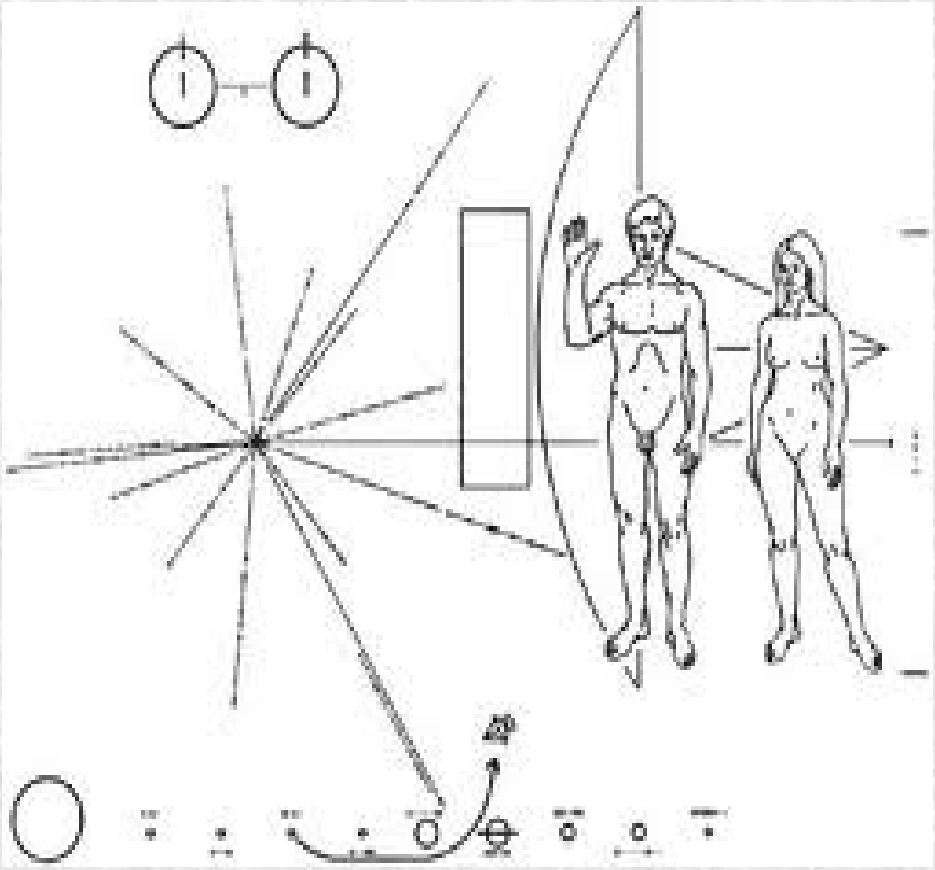
Titan: Largest Moon of Saturn



Cassini-Huyghens Mission; NASA/ESA

- Titan has a thick but cold atmosphere – the only moon with an atmosphere
- The atmosphere is nitrogen, with some hydrocarbons which produce “weather”
- Temperature (-180C) is probably too low for life to begin

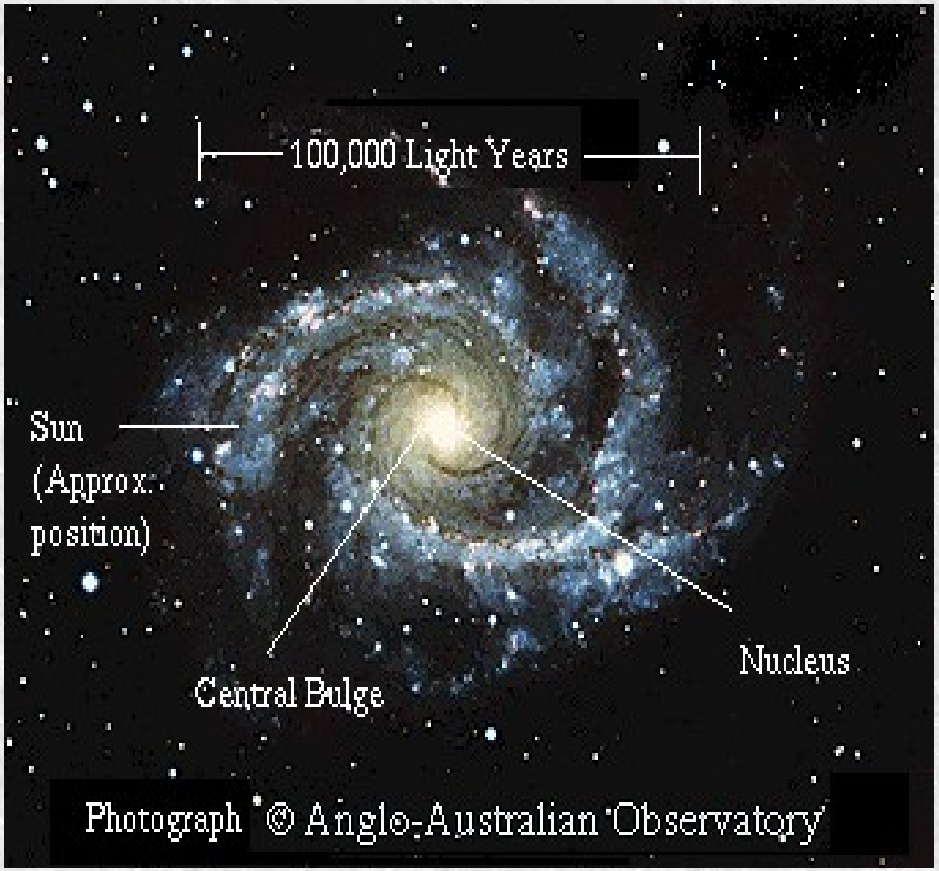
The Pioneer Plaque and Voyager Record – A Symbolic Message to ETI



NASA

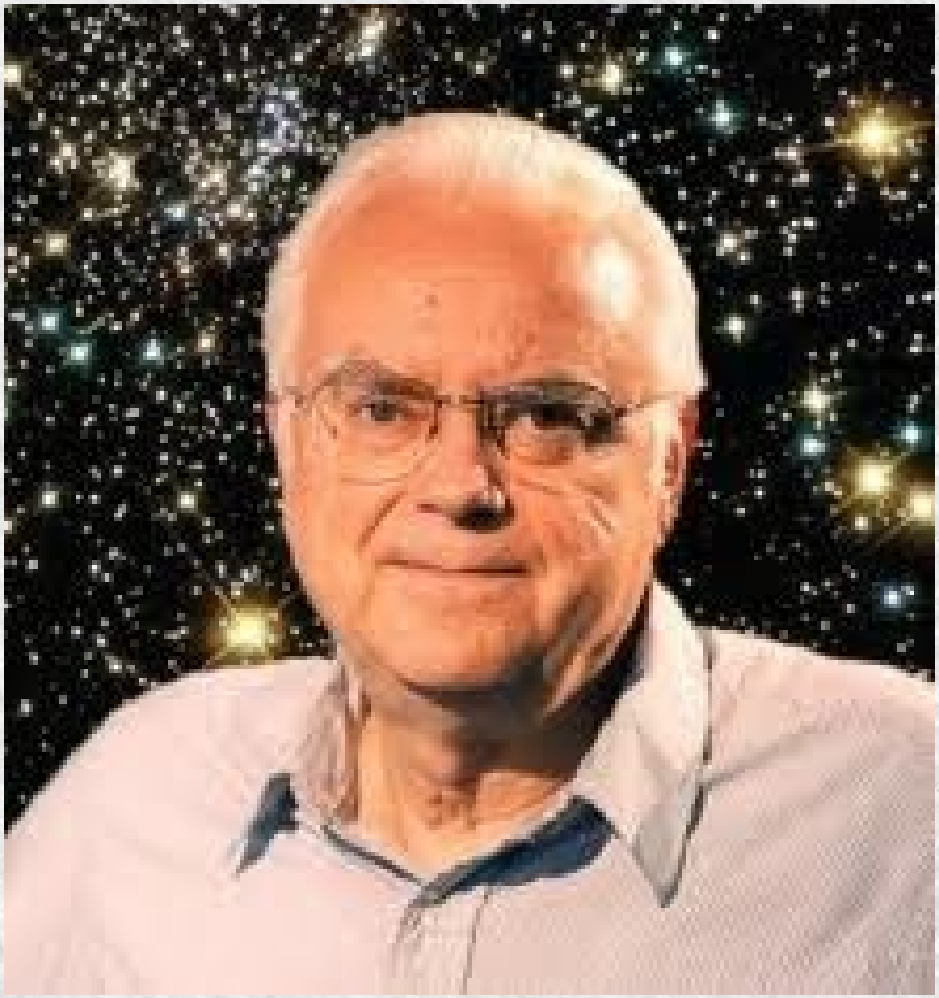
Life beyond our solar system?

Our Milky Way Galaxy



- Hundreds of billions of stars – most of them twice as old as the sun
- Gas and dust
- 90% “dark matter” whose nature is unknown
- 100,000 light years across

Drake's Equation



SETI Institute

- Frank Drake was the first to carry out a search for intelligent extraterrestrial radio signals, in 1960
- He developed a crude, but simple and instructive way to estimate how many intelligent civilizations might exist in our Milky Way galaxy, and how far away the nearest might be

Drake's Equation: The Gory Details

The number of communicating civilizations in our galaxy now

=

The number of stars in our galaxy (300,000,000,000)

X

The fraction that last long enough for life to develop (99%)

X

The average number of planets per star

X

The fraction of the planets that are habitable

X

The fraction of these where life develops

X

The fraction of these where intelligence develops

X

The average lifetime of an intelligent, communicating civilization

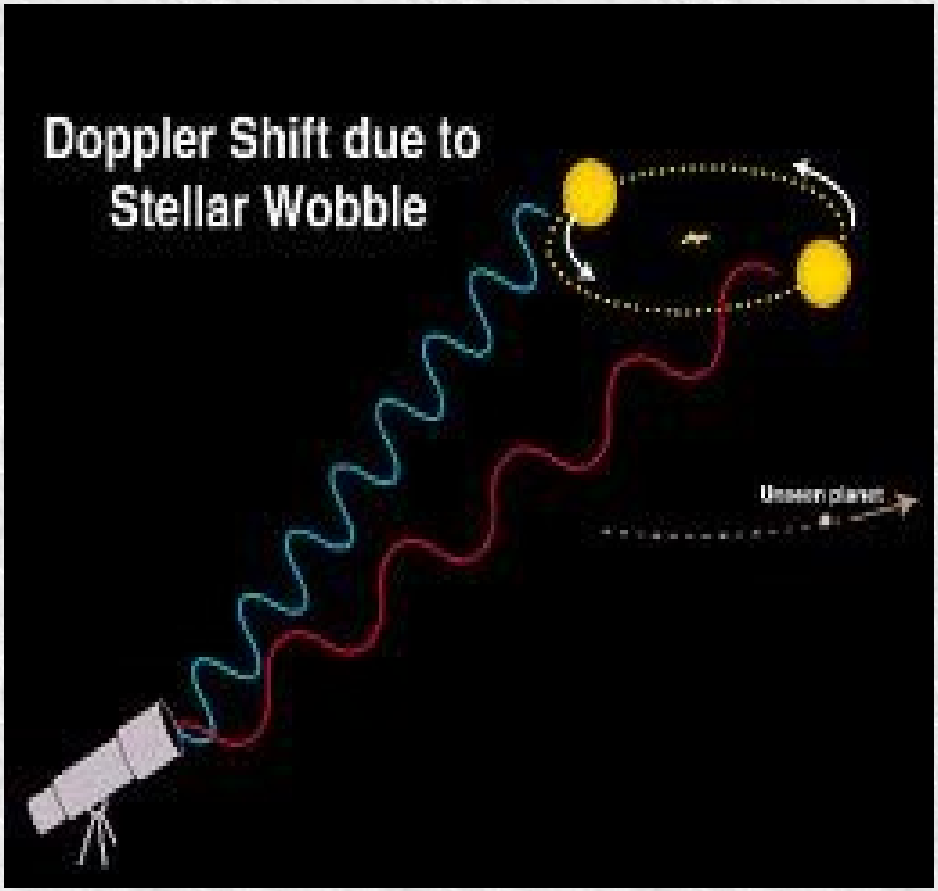
÷

The age of our Milky Way galaxy (10,000,000,000 years)

Drake's Equation

- Illustrates the interdisciplinary nature of the problem
- Simplistic
- Weak links in the chain
- Demonstrates the connections to the origin and future of life on earth:
- Number of intelligent, communicating civilizations in our galaxy, now = f(life) x L, the average longevity of a technological civilization

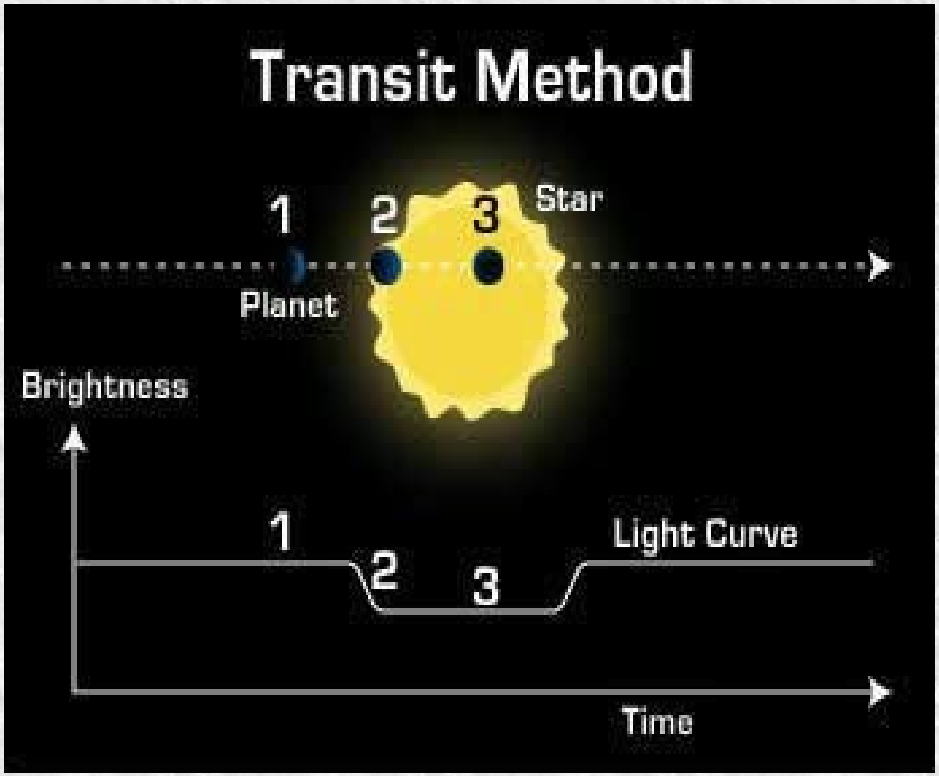
Exoplanets: Detection by their Gravitational Pull on their Star



exoplanets.org

- Exoplanets – planets around other stars, have mass, and therefore gravity; they pull on their star as they orbit
- The star therefore moves in a small orbit, with the same period as the planet
- This motion can be detected with a telescope using spectroscopy and the Doppler effect

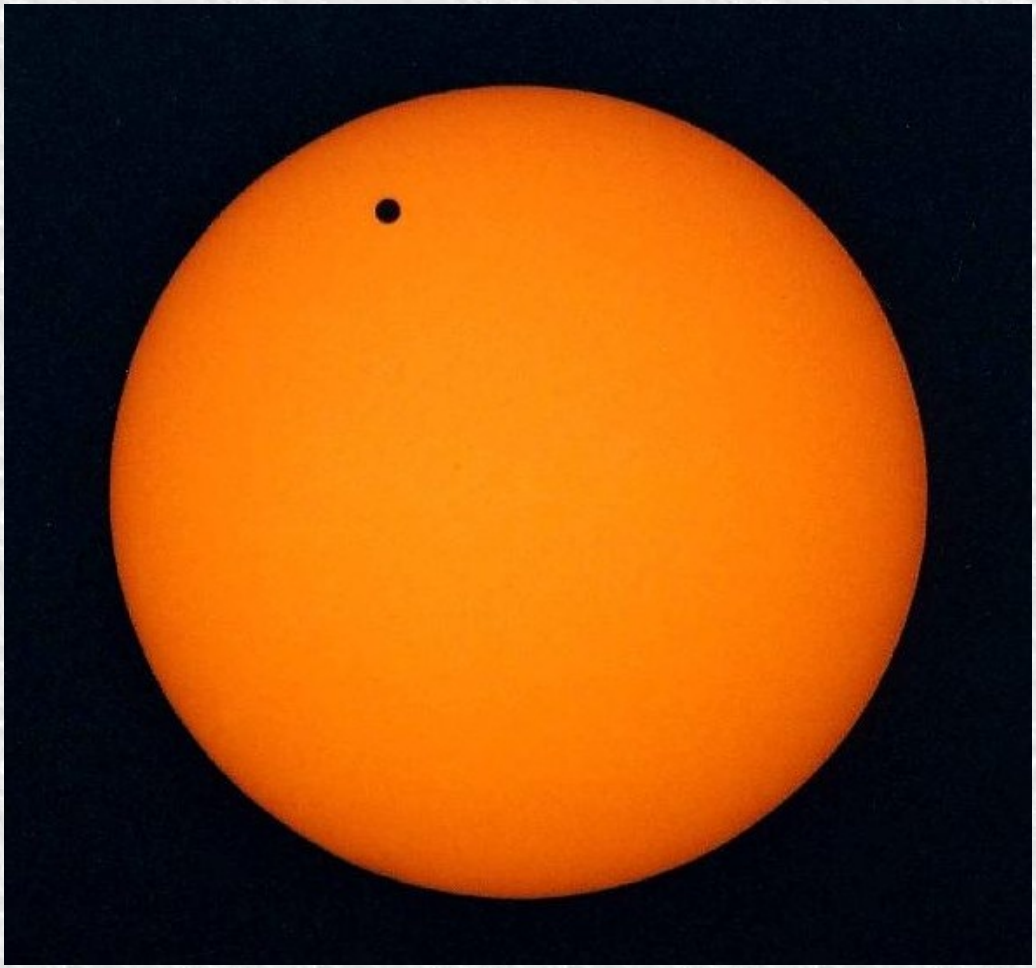
Exoplanets: Detection by Transits



exoplanets.org

- If the orbit of the exoplanet is edge-on, the planet transits, or passes in front of its star, once each orbit
- The brightness of the star dims slightly, by an amount that depends on the size of the planet
- This can be detected and studied by measuring the changing brightness of the star

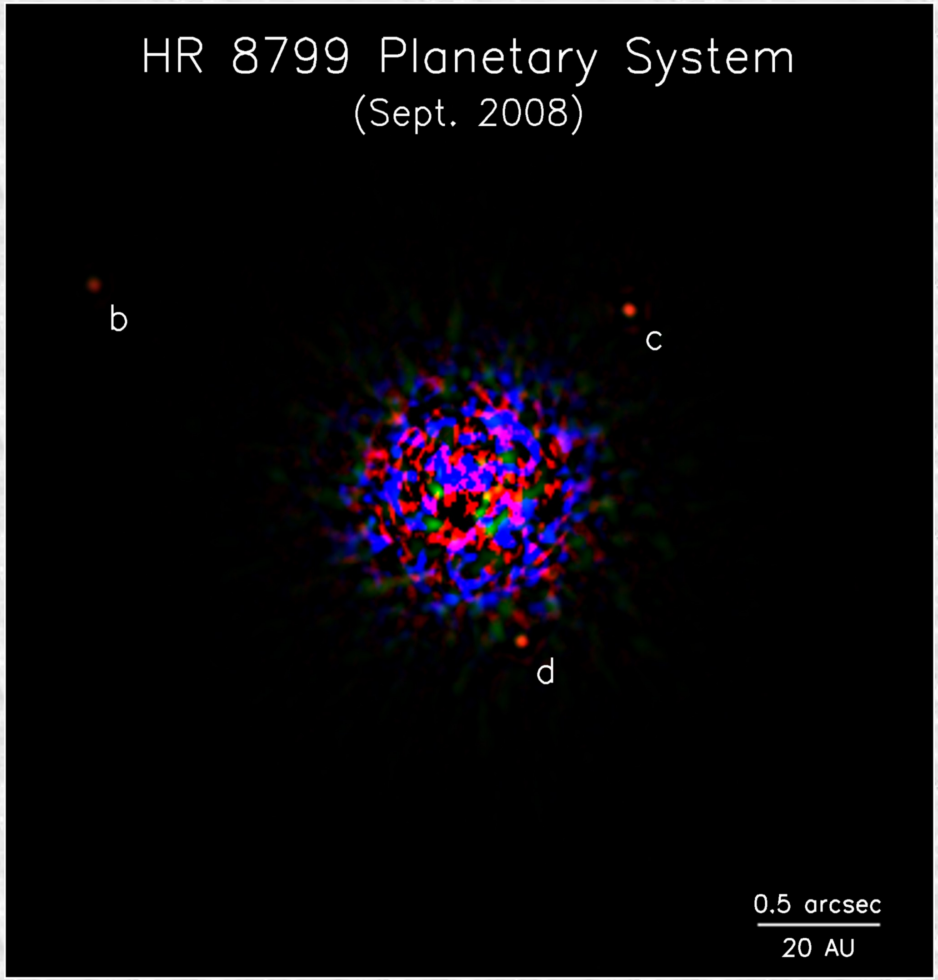
Transit of Venus



- Venus appears to pass across the face of the sun
- This rare event occured on Tuesday, June 5, 2012
- The next transit will not occur for over a century!

NRAO

Exoplanets: Direct Imaging



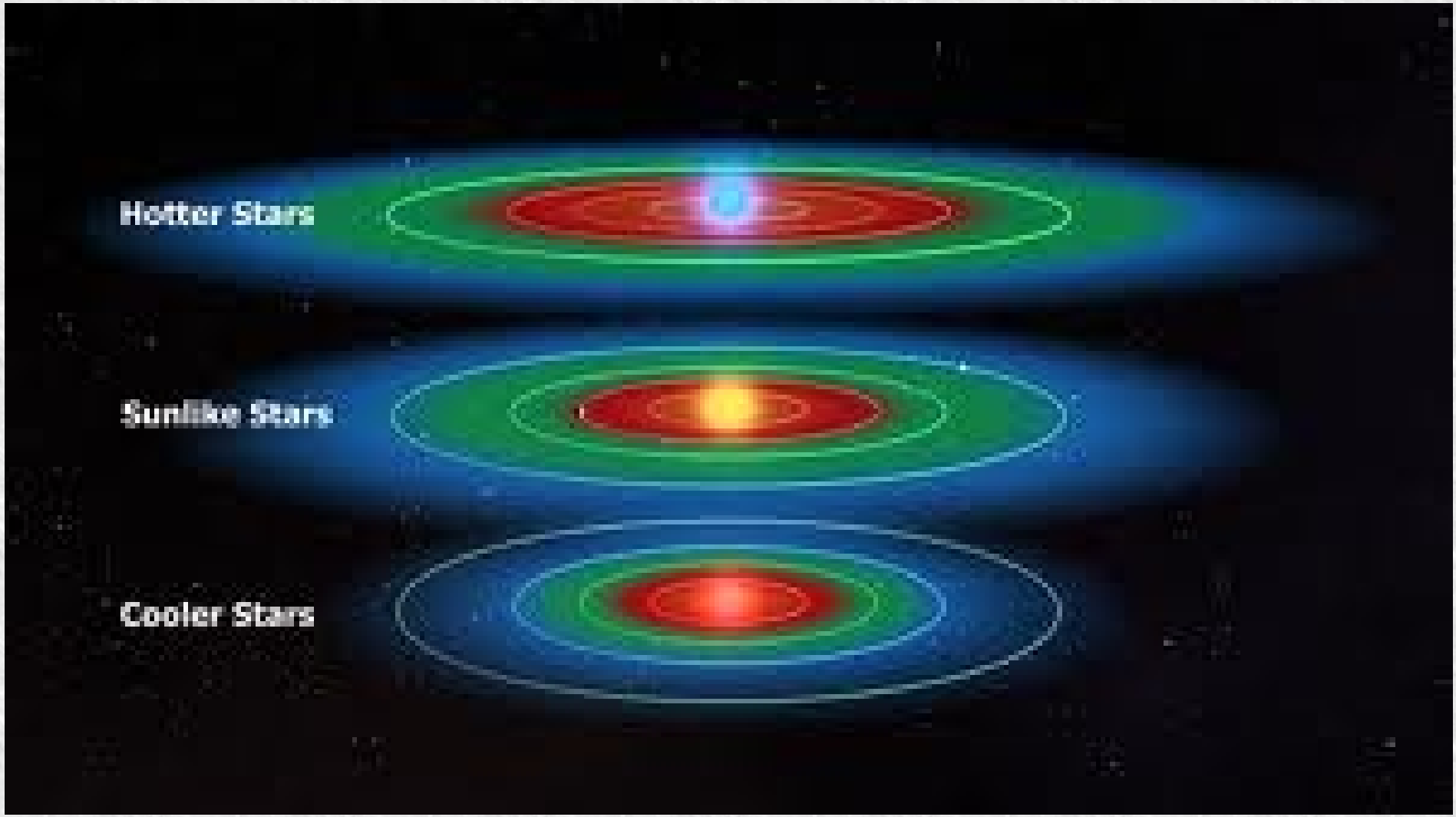
National Research Council of Canada

- Imaging an exoplanet is very difficult, because the star is a billion times brighter than the planet, which is very close to it
- The light of the star needs to be suppressed by a factor of almost a billion
- Canadian astronomers were part of the team that obtained the first image of an exoplanet

Habitable Zones

where water is liquid

Cooler stars common; hotter stars rare

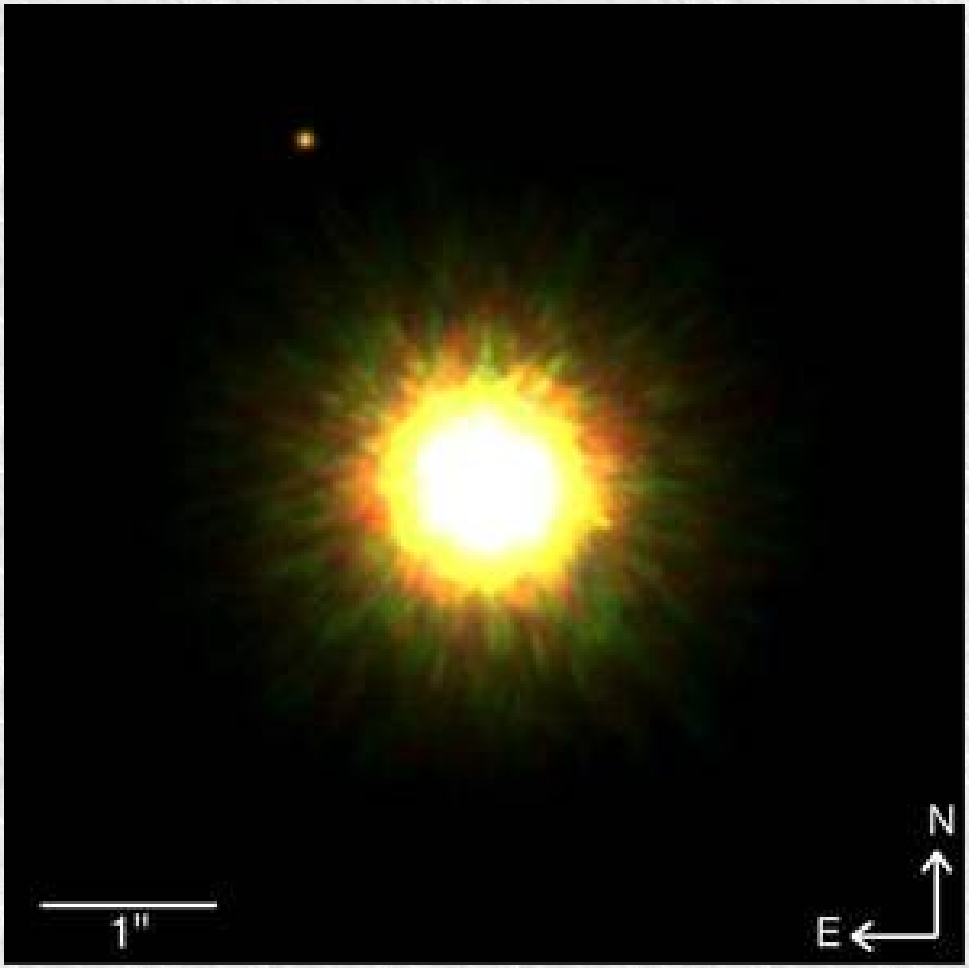


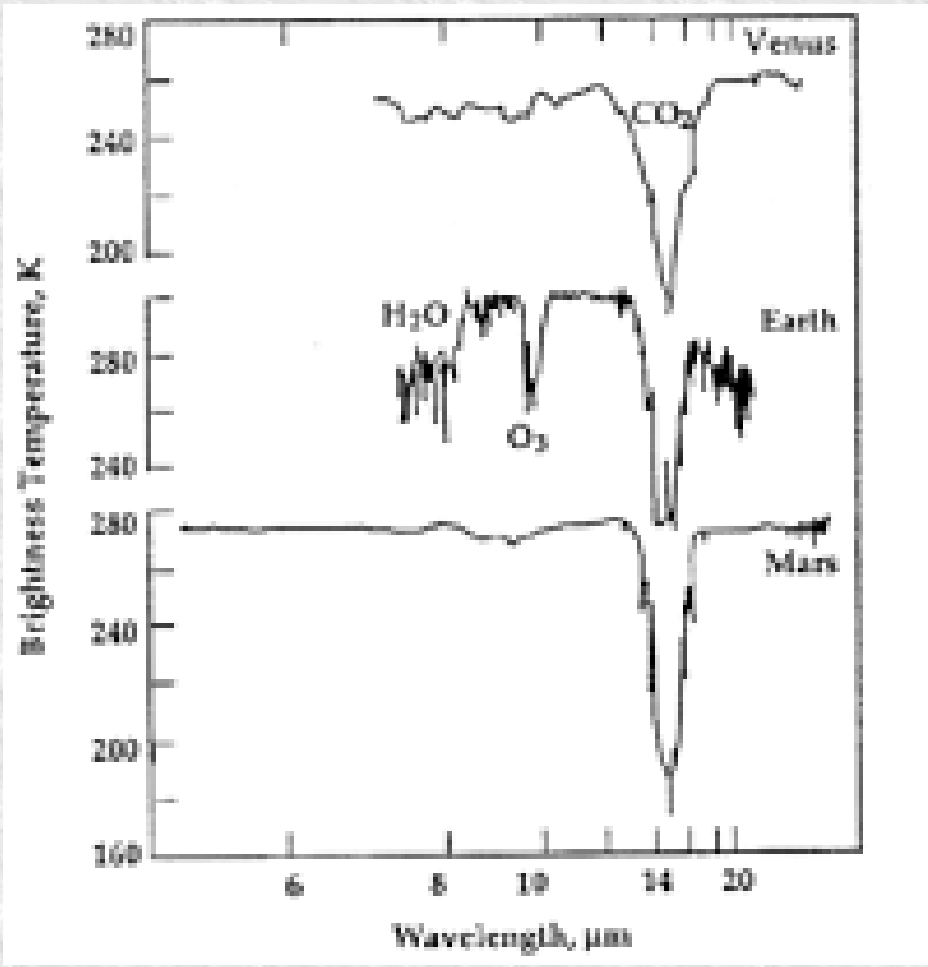
NASA: Kepler Mission

Detecting Life Beyond the Solar System

- Spectroscopic detection of biologically produced molecules, such as oxygen and methane, in the atmosphere of an exoplanet
- Detection of a signal (radio, light) that was not of natural origin, and must therefore be artificial: (i) a simple beacon; (ii) a message
- Direct contact: extraterrestrial life forms land on earth

Spectroscopic Detection of Simple Life
spectroscopic signatures of biogenic molecules





National Research Council of Canada

Interstellar Communication

Interstellar Communication

using electromagnetic radiation e.g. radio

- Can be done with existing technology
- Travels at the speed of light
- Requires relatively little energy
- Doesn't get you there in person

Interstellar Radio Communication

Algonquin Radio Observatory, NRC Canada

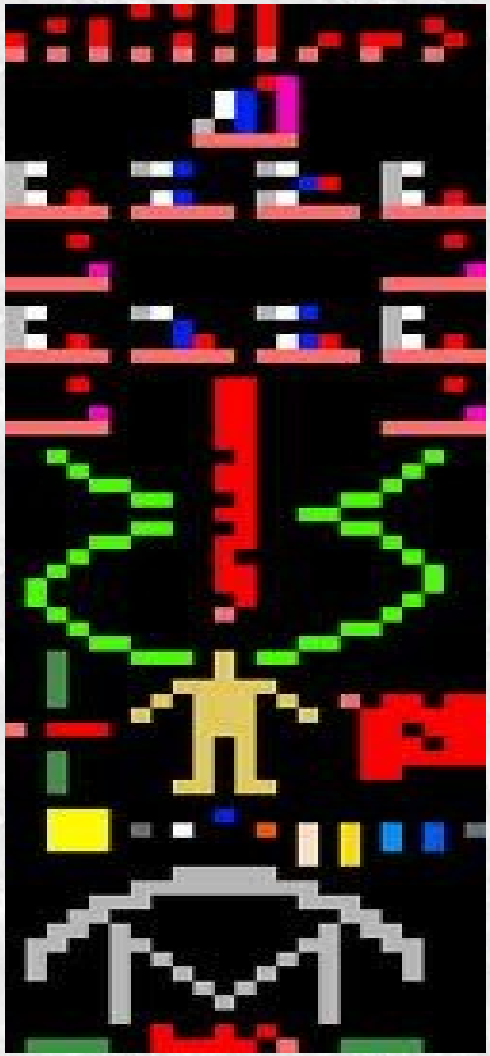
- Radio waves travel at the speed of light
- They are unhindered by interstellar dust and gas
- We can (i) produce them cheaply, (ii) encode them with information, and (iii) detect them with radio telescopes
- Searches for extraterrestrial signals have been underway for 50 years

Interstellar Radio Communication: What Might We Detect?

CN Tower, Toronto

- If the detected signals are like those emitted from the earth, the strongest radio waves would be:
- Planetary research radars (rare)
- Deliberate signals (rare)
- Military radars (not rare!)
- TV carrier (not information) signals
- FM carrier signals

What “Language” To Use?



Arecibo Observatory

- This pictograph was sent, in binary code, in a 3-minute message from Arecibo Observatory; can you understand it?
- Send a beacon? Prime numbers (1,2,3,5,7,11 ...)? A pictograph like the one at left? A message in a carefully constructed language?

Interstellar Radio Communication: present status

SETI Institute, Allen Array

- Regular radio telescopes have surveyed the sky for signals for a few hundred hours
- Privately-funded SETI telescopes have surveyed for much longer; the SETI Institute Allen Array is “the state of the art”
- No signals have yet been detected

Interstellar Travel

The problem is distance; with present technology, it would take a million years to reach nearby stars

Interstellar Travel

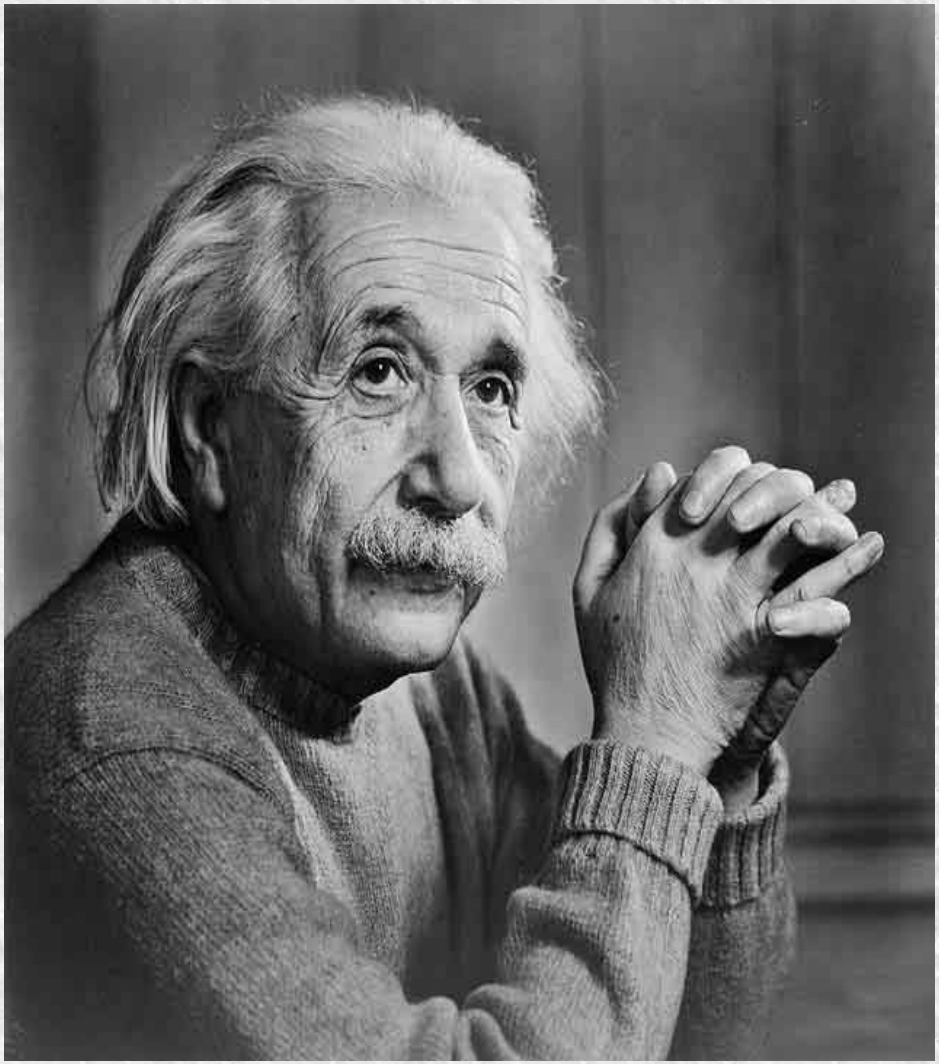
- Presently: would require 100,000 years to reach the nearest star
- Requires a great deal of energy, especially to travel fast: $E = \frac{1}{2}$ mass x (speed)^2
- Can only go one place at a time
- What's the motivation?
- Get's you there in person

How Rockets Work:
very inefficiently!

NASA

- Chemical fuel is oxidized/burned and heated
- It expands, and is driven out the rocket exhaust
- The rocket and payload are pushed in the opposite direction; “action equals reaction”
- But the rocket must carry fuel for all future needs -- massive!

Interstellar Travel:
An Assist from Useful Relativistic Effects

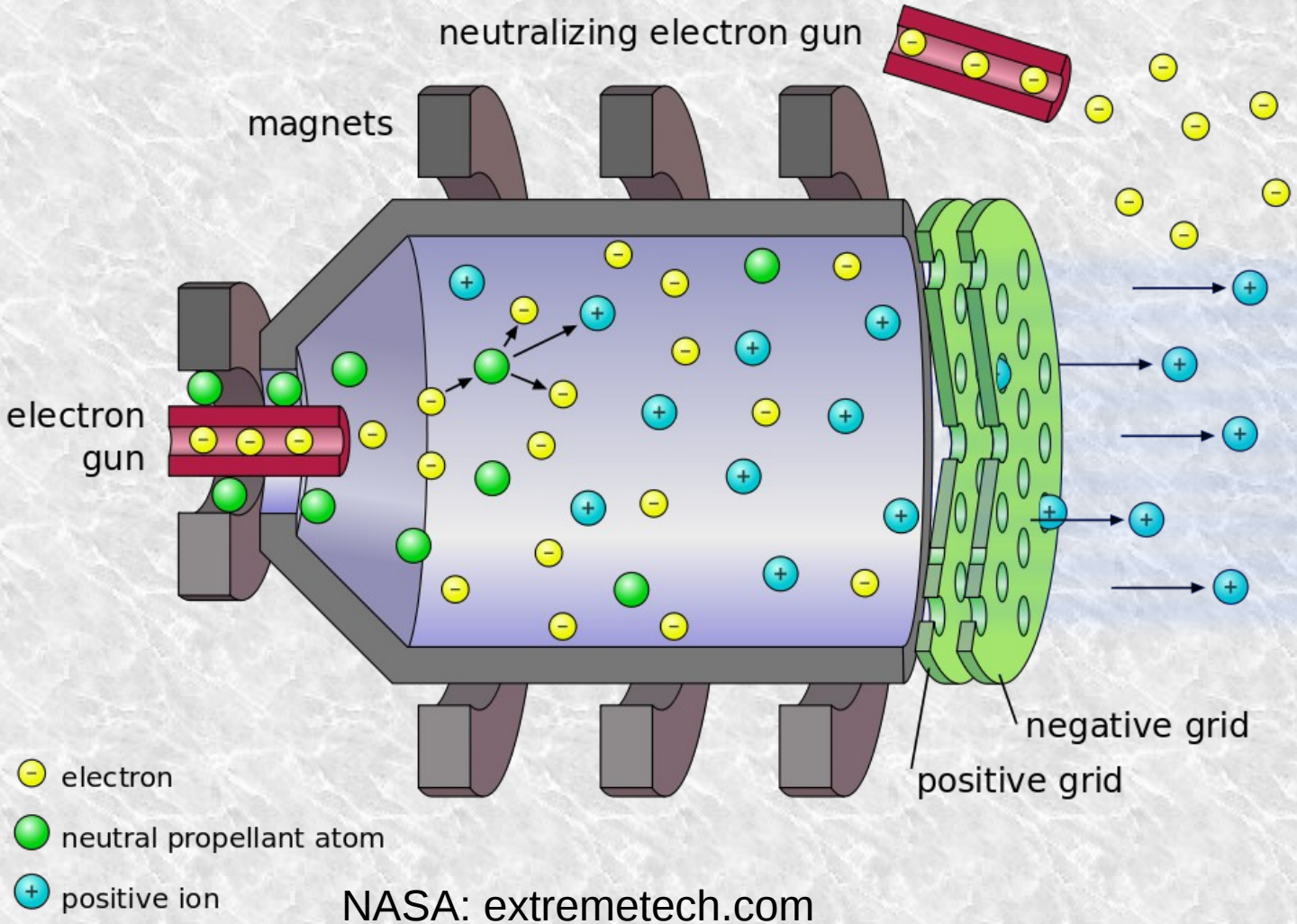


Karsh of Ottawa

- According to the Special Theory of Relativity, objects travelling near the speed of light will experience time slowed down
- A twin, sent at such speeds on an interstellar voyage, will return to earth to find his/her twin aged or dead!
- Would require enormous energy!

Advanced Propulsion Systems

İon drive: accelerate and expel ions – charged particles



NASA: extremetech.com

Project Orion: recycles undesirable nuclear weapons!

NASA

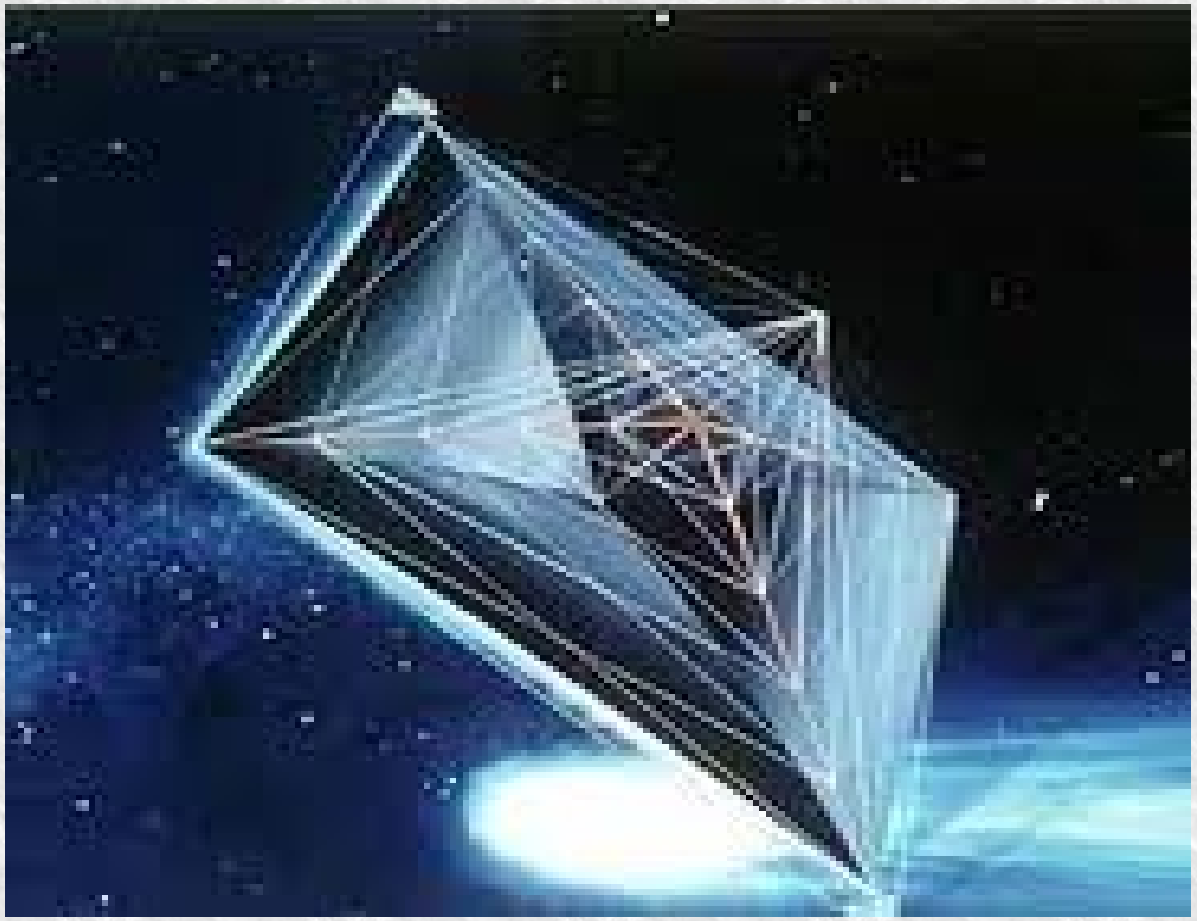
Project Daedalus: hydrogen fusion; efficient technology; may be feasible in a few decades

Joe Bergeron

Ramjet uses interstellar hydrogen gas as fuel; for fusion collect your fuel as you go along

Joe Bergeron

Sail by sun/starlight or powerful laser on Earth; has been tested on a small scale

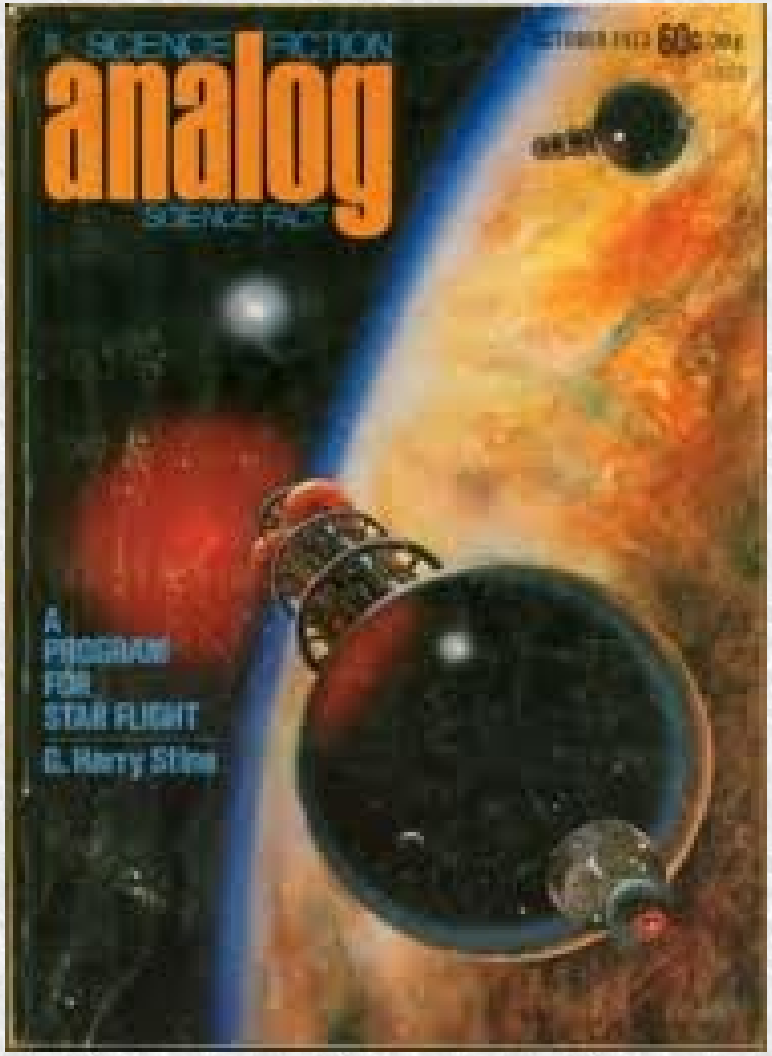


Joe Bergeron

Antimatter Drive: producing antimatter is impractical, as is storing it!

NASA/JPL: daviddarling.com

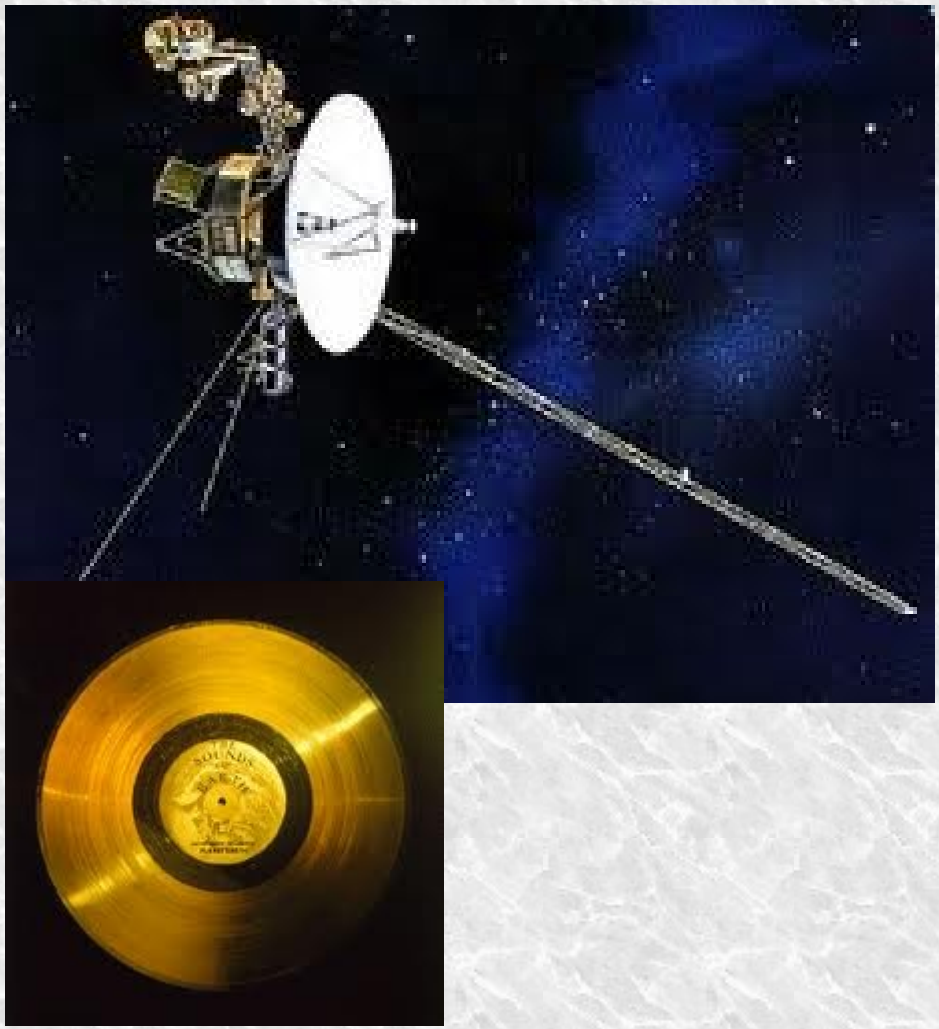
Generation Starships



Analog Magazine

- If the voyage will take thousands of years, send a large community of colonists on a starship
- The descendents of the original colonists, many generations later, will arrive at the destination (maybe)

The Advantages of Sending Robots



NASA

Voyager 2 and the "golden record"

- For voyages of thousands of years, they are cheaper, simpler, safer
- But they are much slower than signals sent at the speed of light
- And they don't get you there in person!

If We Did Find Extraterrestrial Life, What Might It Be Like?

20th Century Fox

Universal Pictures

“Take me to your leader” Dr. Mazlan Othman

Dr. Mazlan Othman

- Mazlan Othman, a pioneering woman astrophysicist from Malaysia, is now director of the UN Office of Outer Space Affairs
- If extraterrestirals land and ask us to “take them to our leader”, she's it

Where Are “They”?

- They don't exist
- They are very rare
- They self-destruct shortly after they reach our stage of technological development
- They have no more interest in exploring the universe, or making contact with us: “they are at home, living the good life”
- They are watching us carefully, waiting for us to mature
- .....

Points to Ponder

What If?

- Scientists discovered evidence for simple life on a planet around a distant star?
- Scientists discovered a beacon radio signal from a planet around a distant star?
- Scientists discovered an actual radio message from a planet around a distant star?
- Extraterrestrial life really did land on Earth?

Summary

- There are billions of galaxies, each with hundreds of billions of stars, many with planets, made of the same materials and obeying the same laws as in our solar system
- Indirect evidence for extraterrestrial life is therefore strong; they would be our “cosmic cousins”
- There is no direct evidence of extraterrestrial life – yet – but the search is accelerating
- Irrational beliefs in space aliens, and abductions by aliens, are unfortunately widespread

www.astro.utoronto.ca/~percy/EPOindex.htm