



Life, the Universe,  
and Everything

DON'T PANIC

What are  
the biggest questions?

# What are the biggest questions?

- Does God exist?  
(Or, why/how does the universe exist?)
- What happens to us when we die?
- Is there [intelligent] life out there?

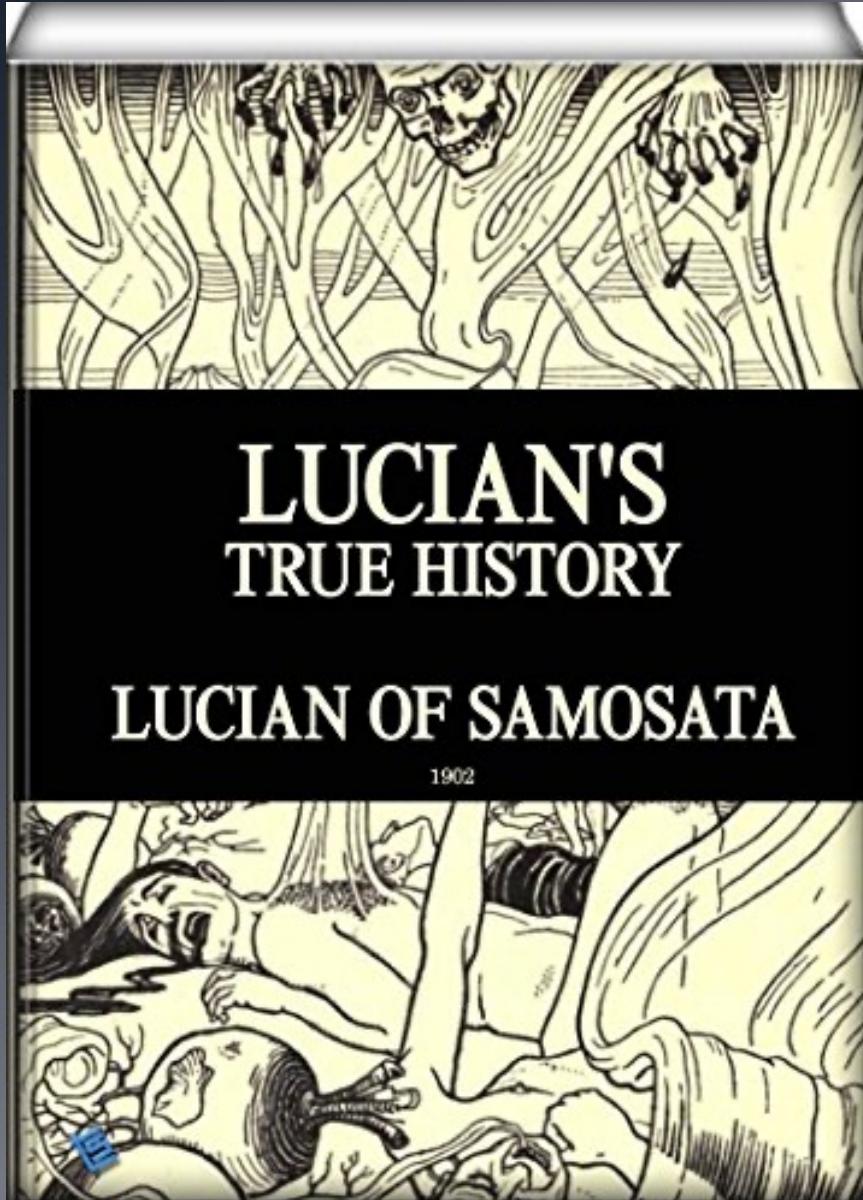
# What are the biggest questions?

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- What happens to us when we die?
- Is there [intelligent] life out there?  
**Only question that might be answerable**

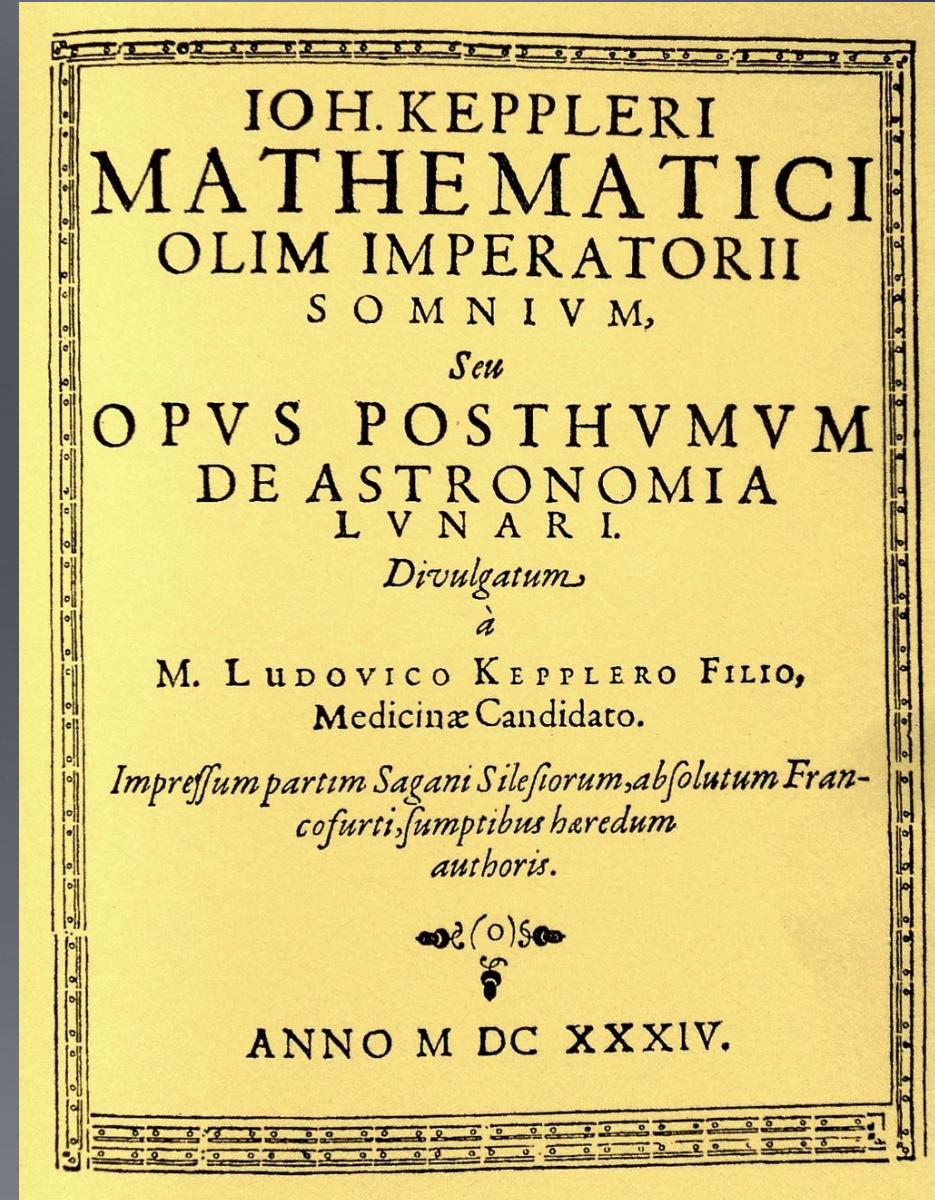
# Are we alone?



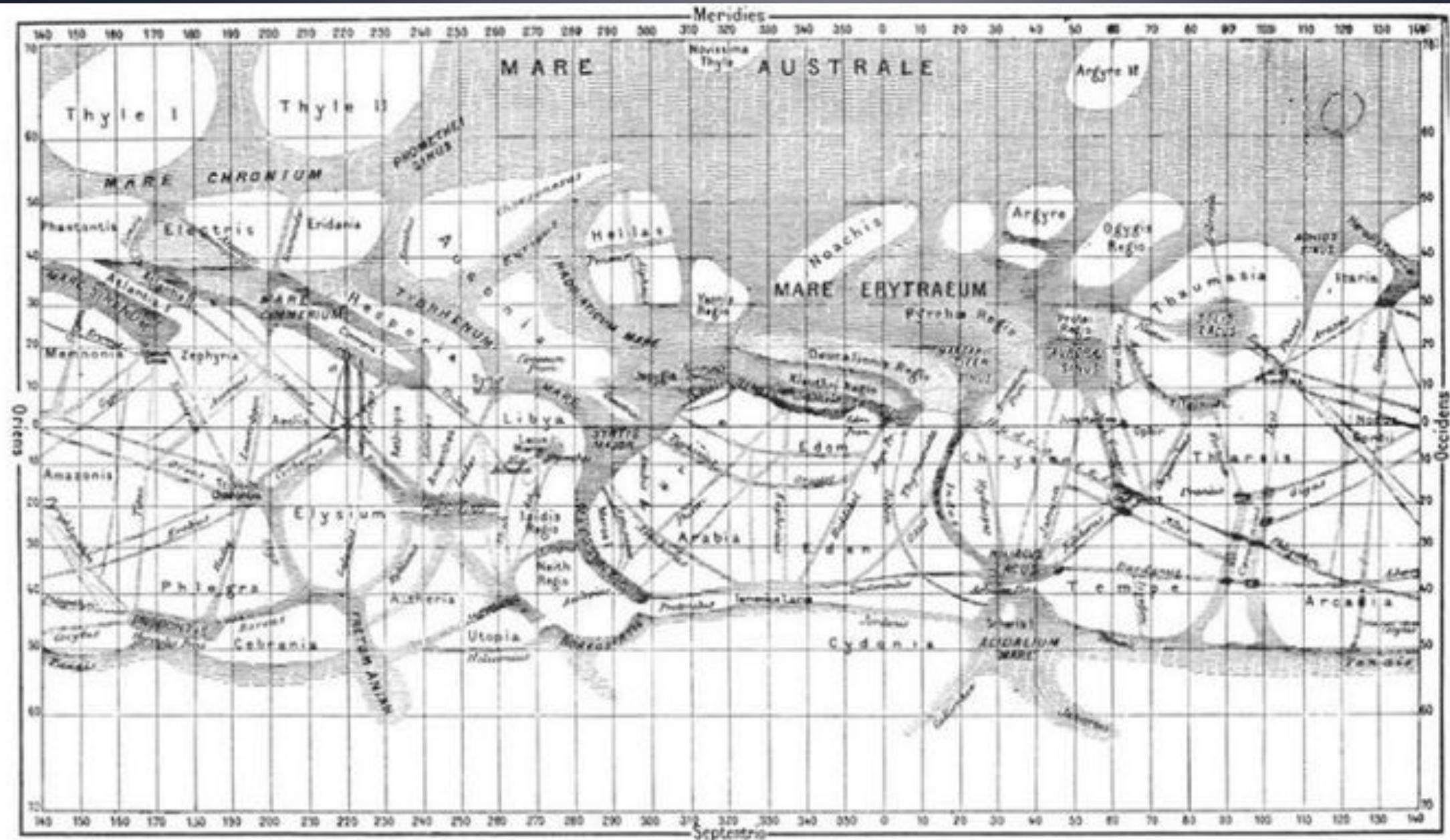
Saturn and Earth as viewed from the Cassini Spacecraft



Lucian: 2<sup>nd</sup> century Rome;  
travel to moon



Johannes Kepler: dreams of life  
on the moon



Map of canals on Mars, Giovanni Schiaparelli, 1877

MARTIANS BUILD TWO IMMENSE CANALS IN TWO YEARS

Vast Engineering Works Accomplished in an Incredibly  
Short Time by Our Planetary Neighbors--- .  
Wonders of the September Sky.

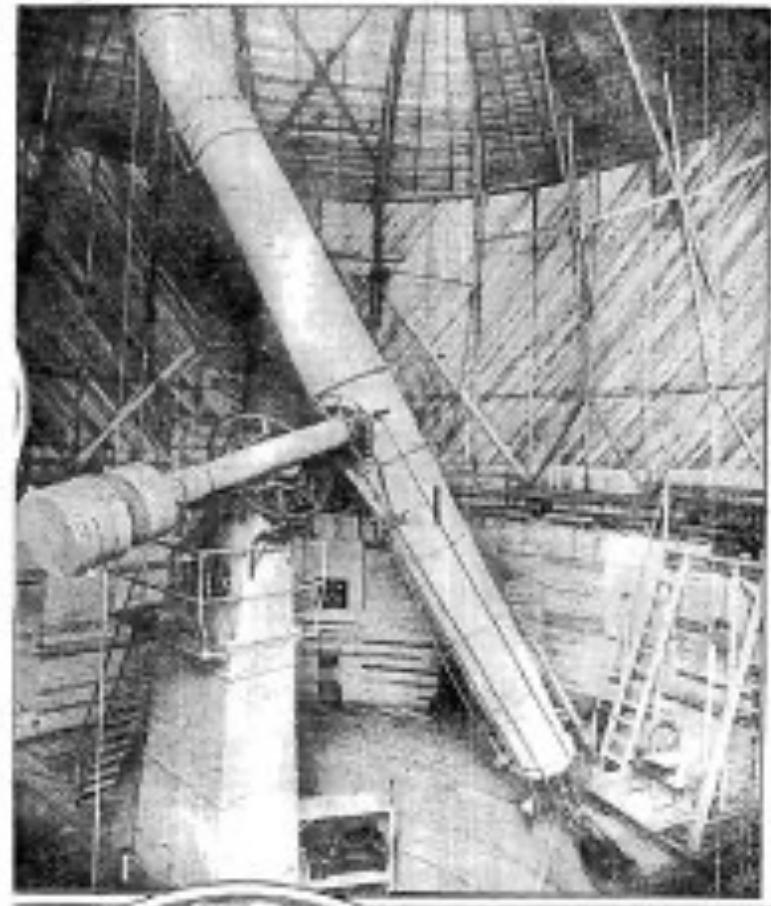
Mr. Harry O'Connell

**A**PPROXIMATELY 10,000 people, mostly Negroes, live in the South Bronx, New York City. The Bronx is one of the most densely populated areas in the United States. The people are poor, uneducated, and unemployed, and their living conditions are among the poorest in the country.

These studies used chlorine because it was the only common halogen available at the time. However, the results of the work have been interpreted as being applicable to iodine as well. The iodine atom has an outer shell of five valence electrons, whereas the chlorine atom has seven. Thus, the iodine atom is less able to attract electrons than the chlorine atom. This makes the iodine atom more easily reduced.

After you have written your first draft, go over it again and make changes as necessary. You may find some words or sentences that don't fit well. You may also find mistakes in punctuation. Once you have made these changes, read your paper again. If you are still not satisfied with your paper, go back and make more changes.

Concerning the Plymouth car, see the note above from Adolphus Ward, his son from whom he obtained it, as well as the note of James Franklin.



#### The Great Teachers of Leviticus

had at one time claimed to have beaten, respectively the members of his party, while he had espoused the anti-slavery cause. That he made himself master of every available source for the study of all subjects relating thereto, including American history. The older boys in the neighborhood used to be instructed without the aid of any books or printed papers, a system which

# New York Times, 1911

**FROM OUT OF SPACE....  
A WARNING AND AN ULTIMATUM!**



WITH

**MICHAEL RENNIE · PATRICIA NEAL · HUGH MARLOWE**

SAM JAFFE · BILLY GRAY · FRANCES BAXTER · LOCK MARTIN

PRODUCED BY JULIAN BLAUSTEIN · DIRECTED BY ROBERT WISE · SCREEN PLAY BY EDMUND H. NORTH

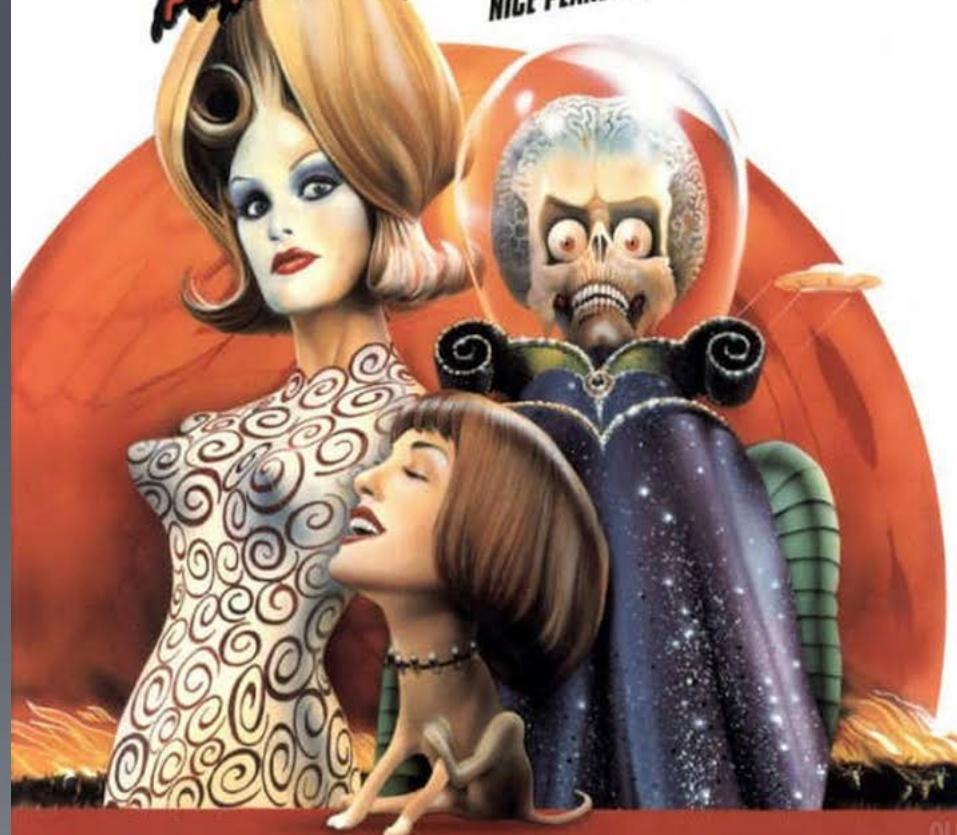
20<sup>th</sup> CENTURY FOX

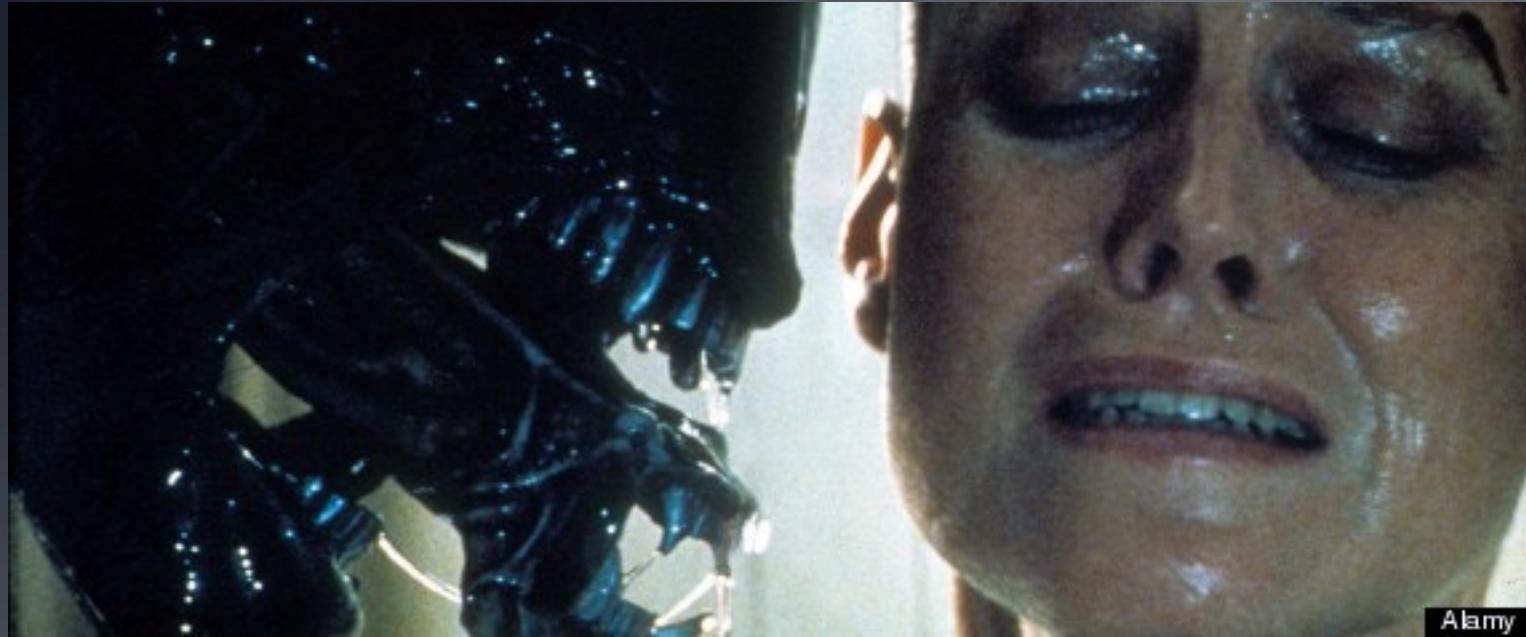
JACK NICHOLSON GLENN CLOSE ANNETTE BENING PIERCE BROSNAN DANNY DEVITO

DVD

**MARS ATTACKS!**

NICE PLANET. WE'LL TAKE IT!







# Search for Extra-Terrestrial Life (SETI)

- Began in ~1960s
- TV still new
  - Radio signal for decades
- Radio telescopes!
  - New technology
  - Lots of photons
  - No absorption in interstellar medium

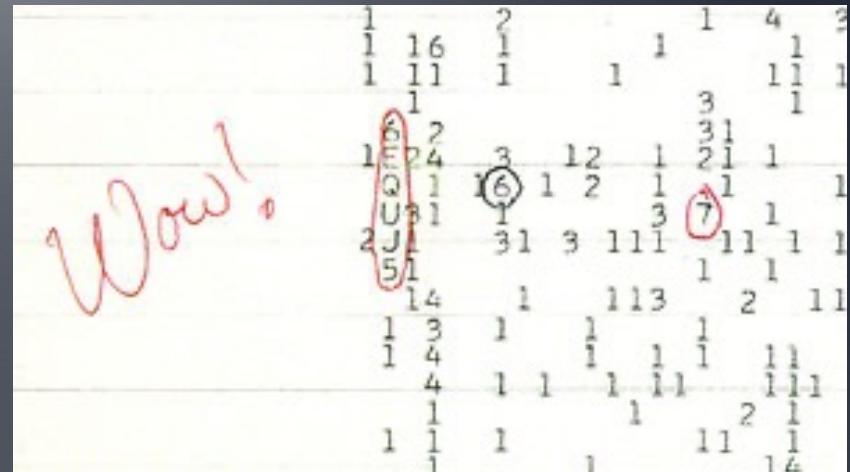


# The WOW signal

- Strong, narrowband radio signal detected on 1977.08.15
- Lasted 72 seconds
- Not repeated again

## Problems with SETI

- Not repeatable
- No firm test (scientific method)
- Weird signals occur frequently
- No good way to guess the right frequency to search for a signal



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Archive > Volume 521 > Issue 7551 > Research Highlights: Social Selection > Article

NATURE | RESEARCH HIGHLIGHTS: SOCIAL SELECTION

Microwave oven blamed for radio-telescope signals

Studies about mysterious signals and super-strong spider silk triggered online chatter.

Chris Woolston

08 May 2015

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A report<sup>1</sup> on the surprising origins of rogue signals picked up by a radio telescope simmers on social media, while researchers on the web commented on an amazing feat of arachnid ingenuity — spinning graphene-laced silk.

After more than four years of searching, researchers using the Parkes radio telescope in New South Wales, Australia, have identified the source of some mysterious signals: a microwave oven in the facility's break room. The news quickly spread on Twitter. Karina Vogel, an astronomy PhD student at the European Southern Observatory in Garching, Germany



John Sarkissian/CSIRO/JPL/NASA

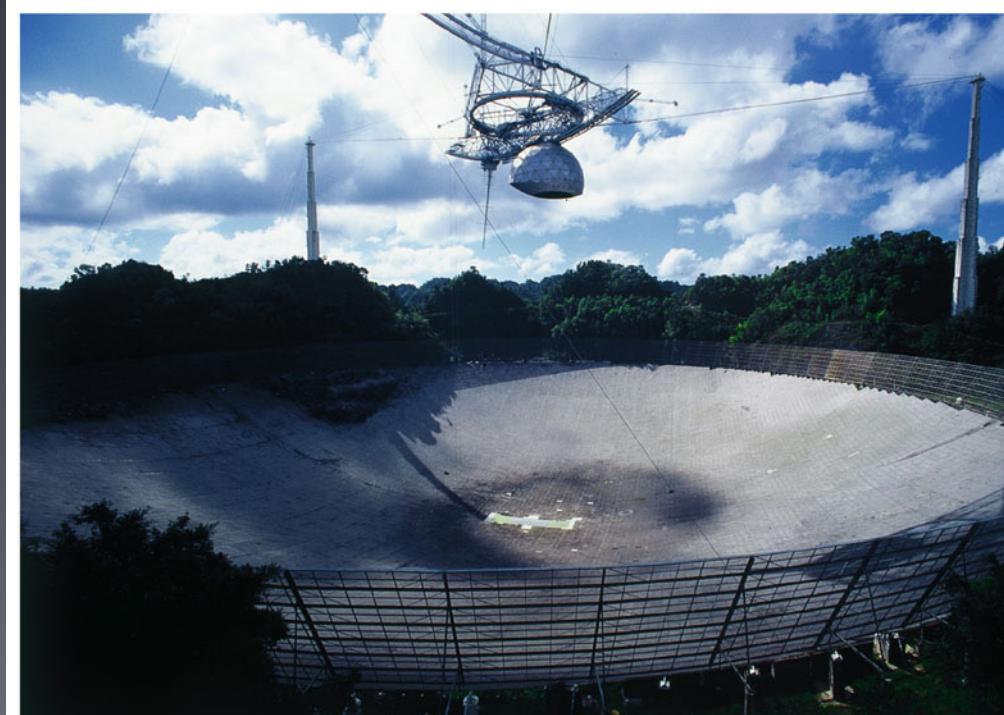
A microwave oven at the Parkes radio telescope in Australia was nabbed as the source of elusive signals.

# Ongoing SETI in the radio

- Secondary science for FAST radio telescope near Guizhou
- Primary science of Arecibo Telescope in Puerto Rico
  - Arecibo Telescope collapsed, so no more



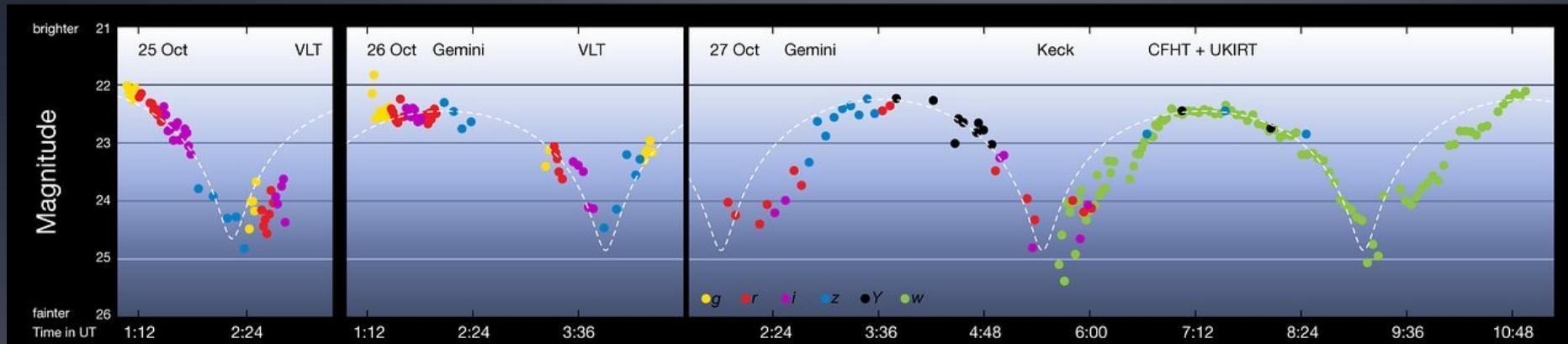
We have even sent a few signals...



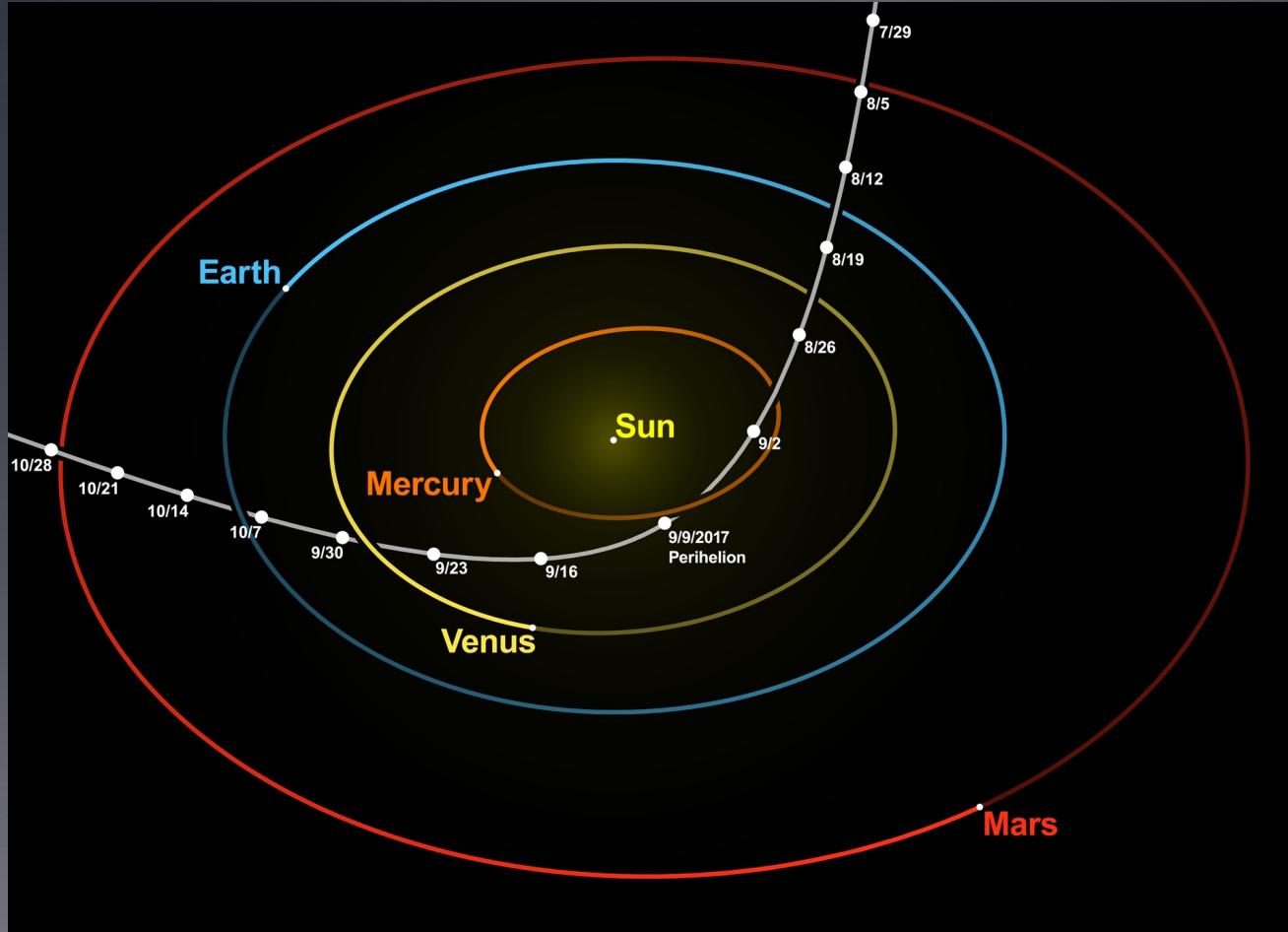
Copyright © 2004 Pearson Education, publishing as Addison Wesley.

Earth to globular cluster M13:  
We could hear back in about 42,000 years!

# An interstellar asteroid: ‘Oumuamua



# An interstellar asteroid/comet: ‘Oumuamua



- Or is it an asteroid?

(despite the next few slides, yes, it's really just a body made of N<sub>2</sub> ice)

# Large Synoptic Survey Telescope

- Very large imager, all-sky every few nights
- Many more weird extra-solar asteroids in future!
- 20 TB/night; total survey: 15 PetaBytes
- Processed using 950 TeraFlops of computing



# Scientific search for extraterrestrial life

- SETI: radio signals
- Searching and characterizing extrasolar planets
- A search for life in our own solar system

# The Drake Equation

Guesstimate number of extraterrestrial civilizations in our galaxy

$$N = N_s \times F_p \times F_l \times F_i \times L_c / L_s$$

**N** is the number of civilizations in the Milky Way today.

**$N_s$**  is the number of stars in the Milky Way.  
**2e11**

**$F_p$**  is the fraction of stars with habitable planets.  
**0.5?**

**$F_l$**  is the fraction of habitable planets with life.

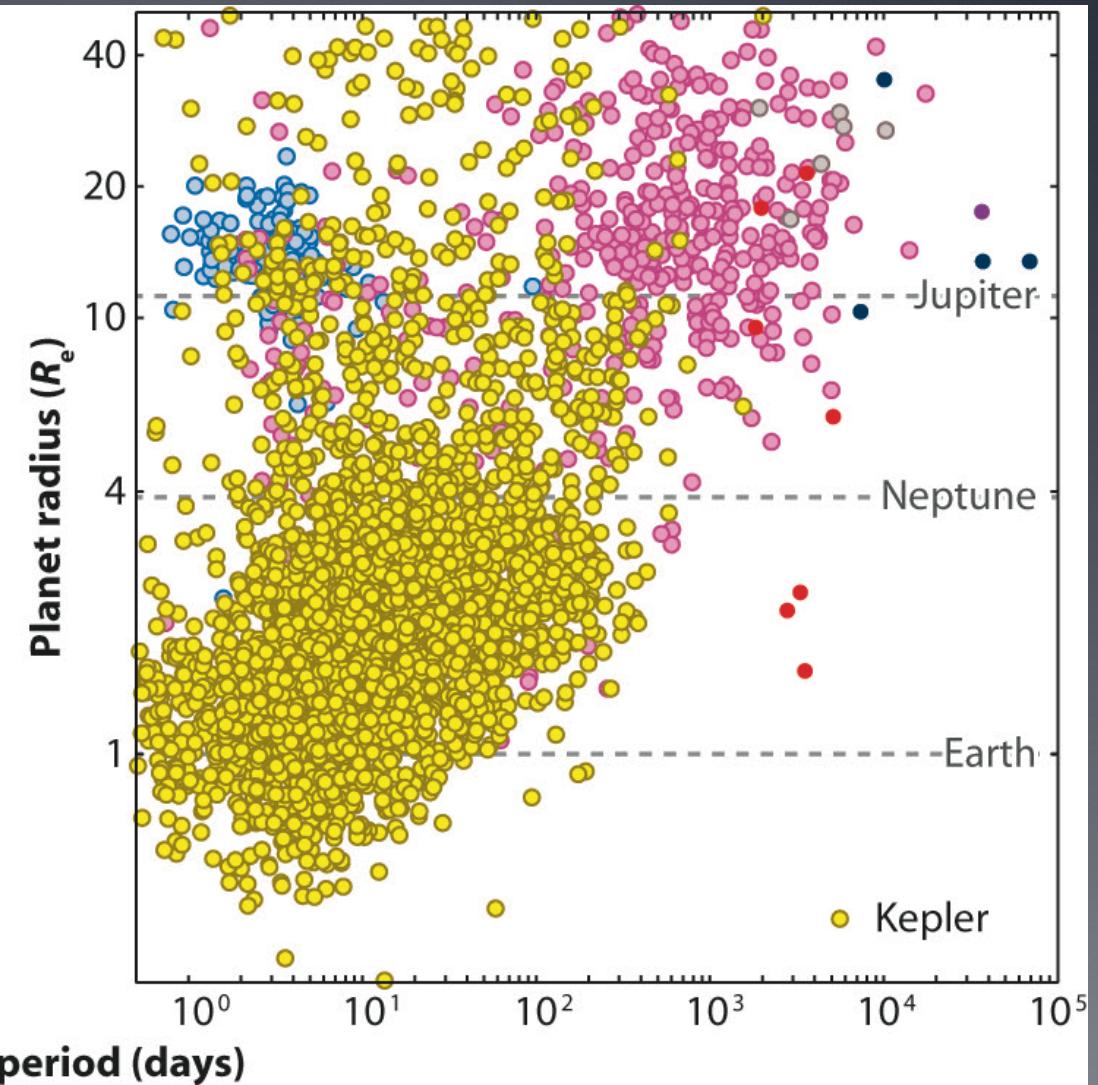
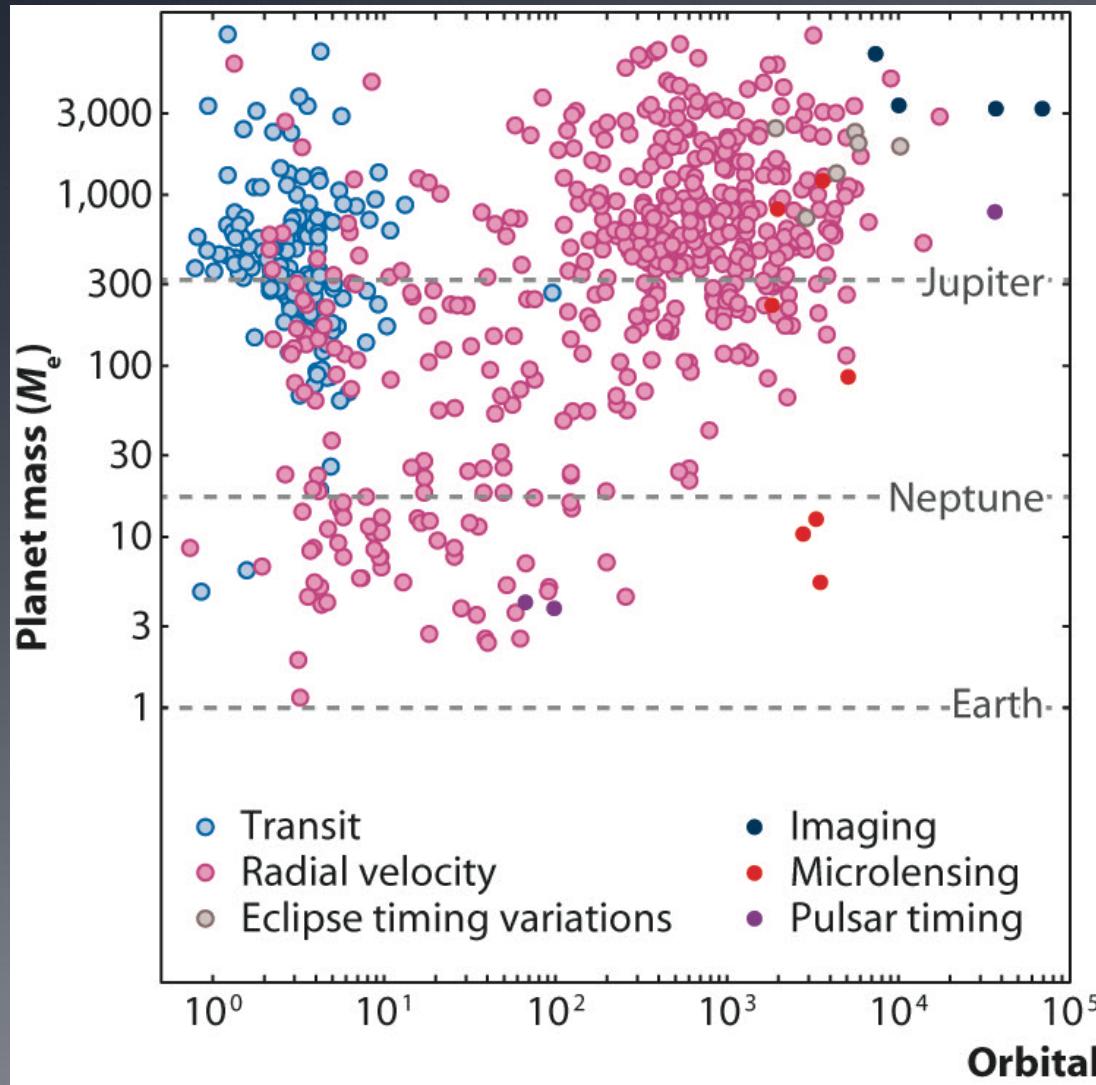
**$F_i$**  is the fraction of life-bearing planets where intelligent civilizations arise.

**$L_c$**  is the typical life-time of a civilization in years.

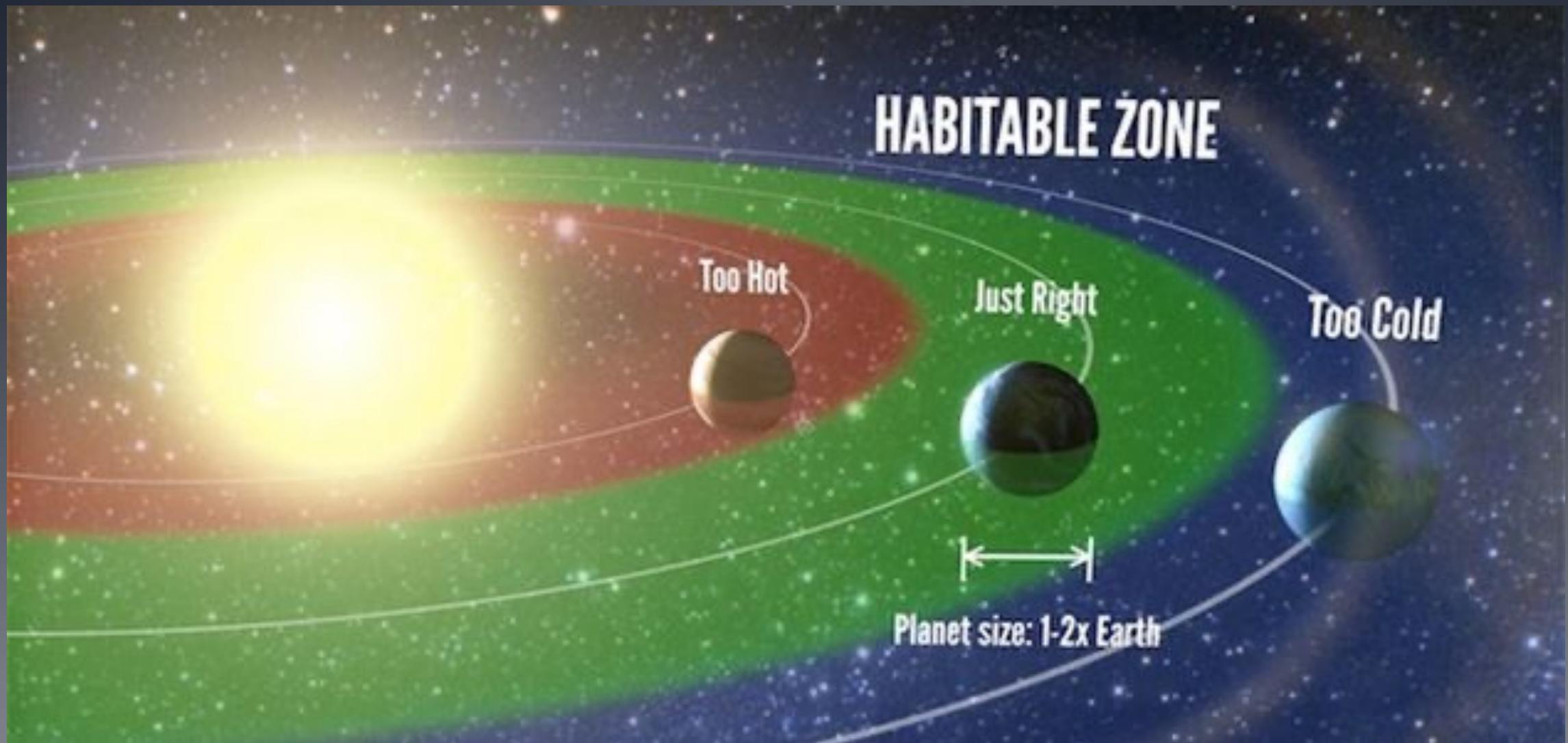
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Is life common?

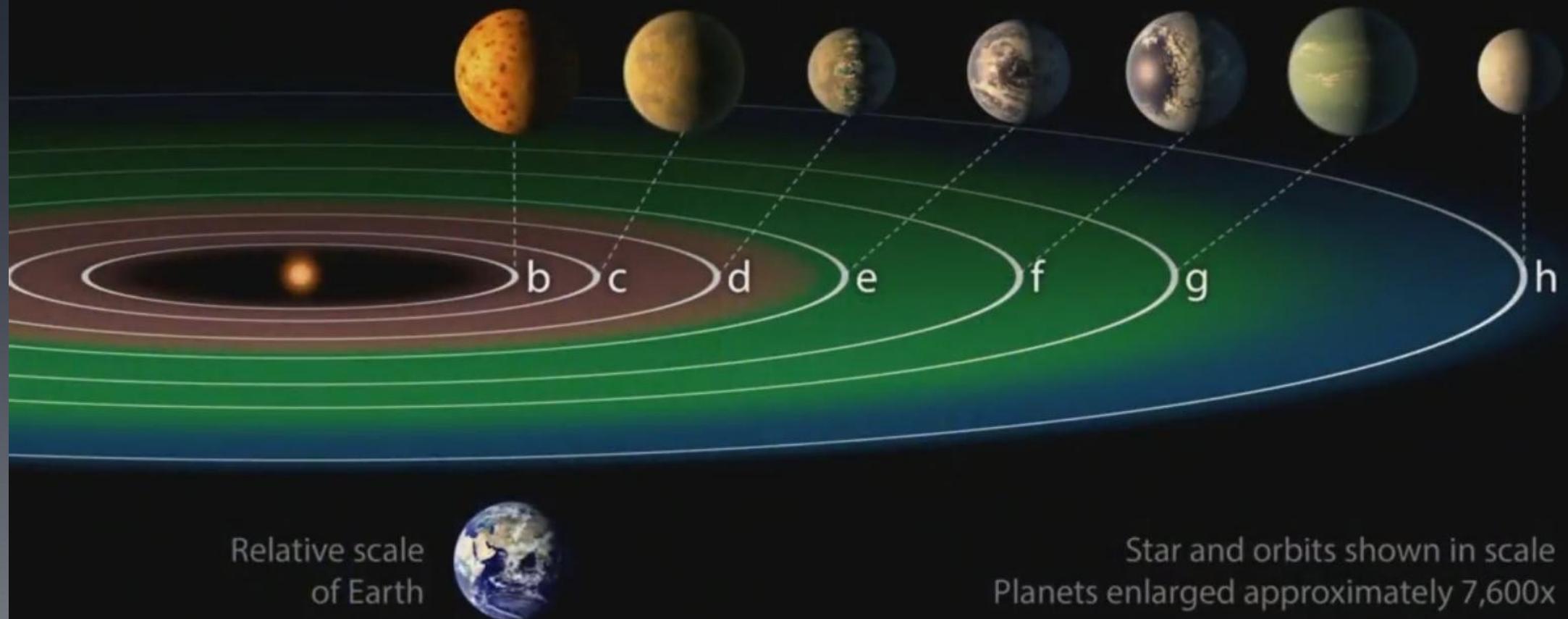
# Exoplanets are common!



# Habitable (liquid water) zone



# TRAPPIST-1 System



# Is life common?

**Testable! Look in our own solar system**

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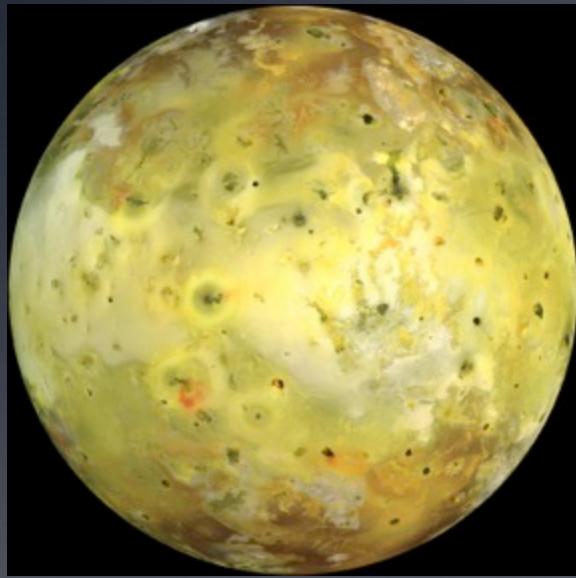
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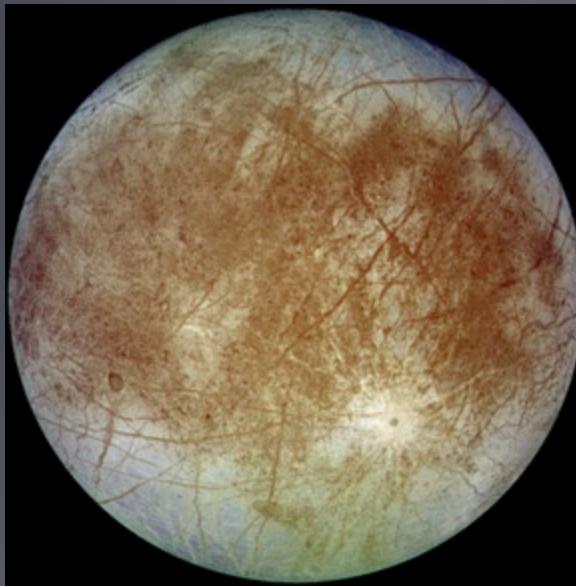
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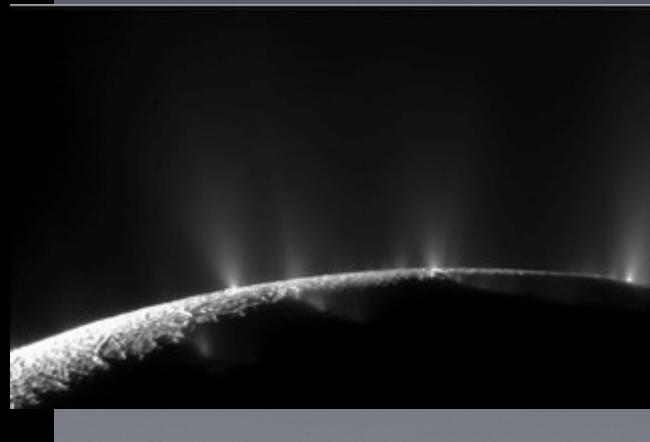
Io (not Titan)



Europa

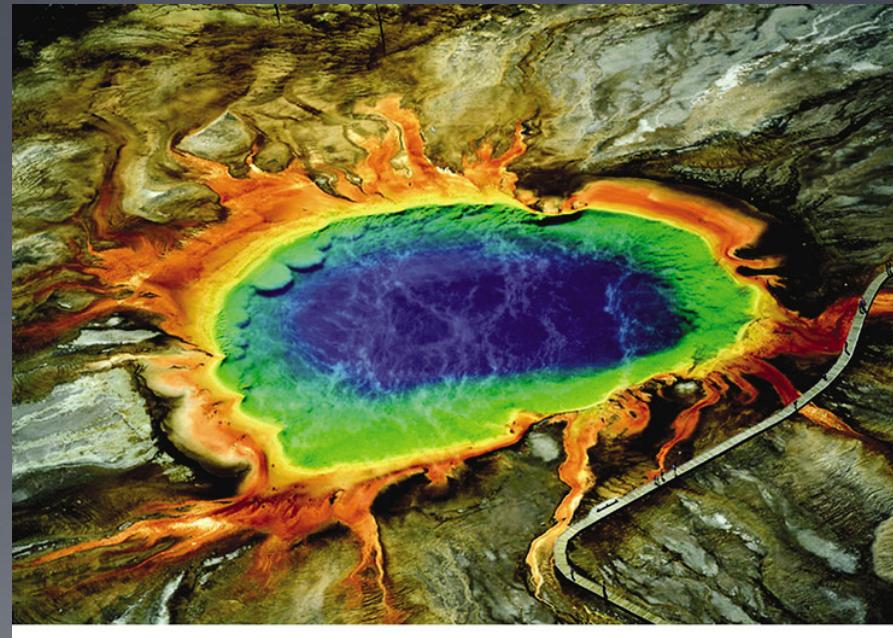
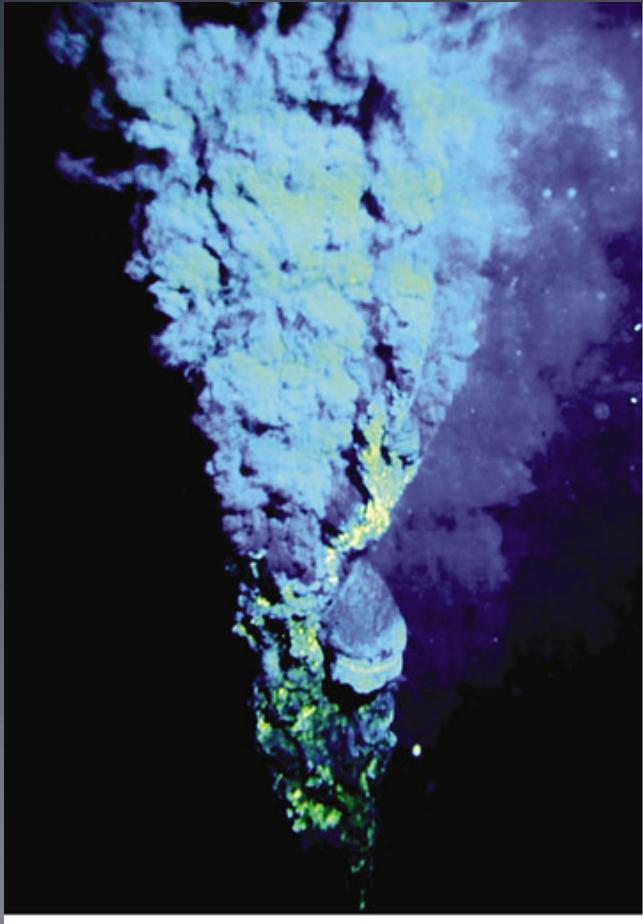


Enceladus



All these moons are heated by tides

- These genetic studies suggest that the earliest life on Earth may have resembled the bacteria today found near deep ocean volcanic vents (black smokers) and geothermal hot springs .

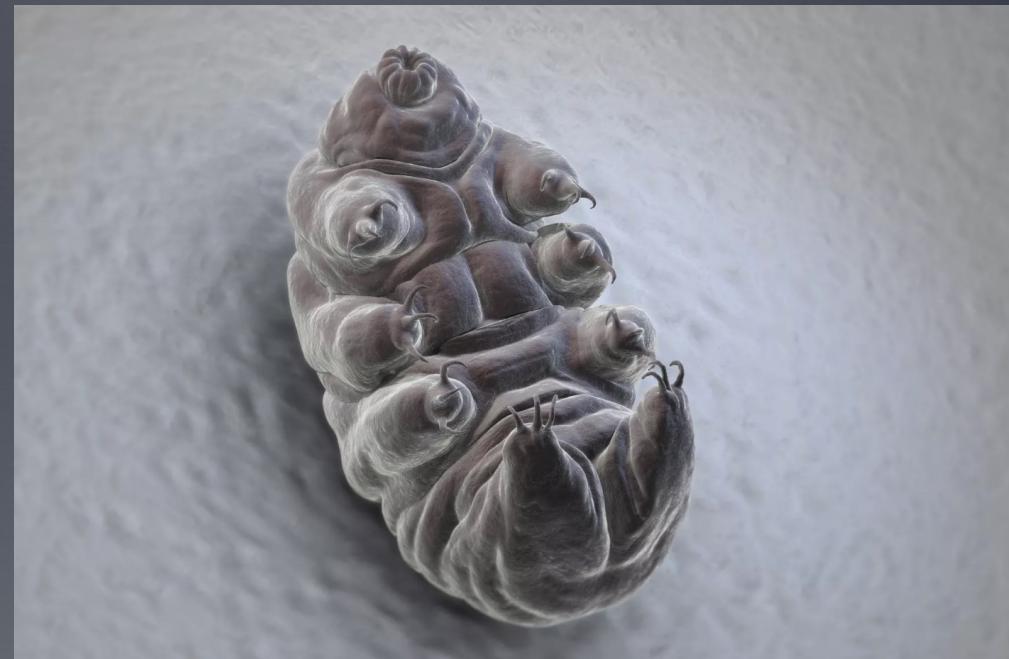


# Tube-worms around 'black-smokers'





# Tardigrades!

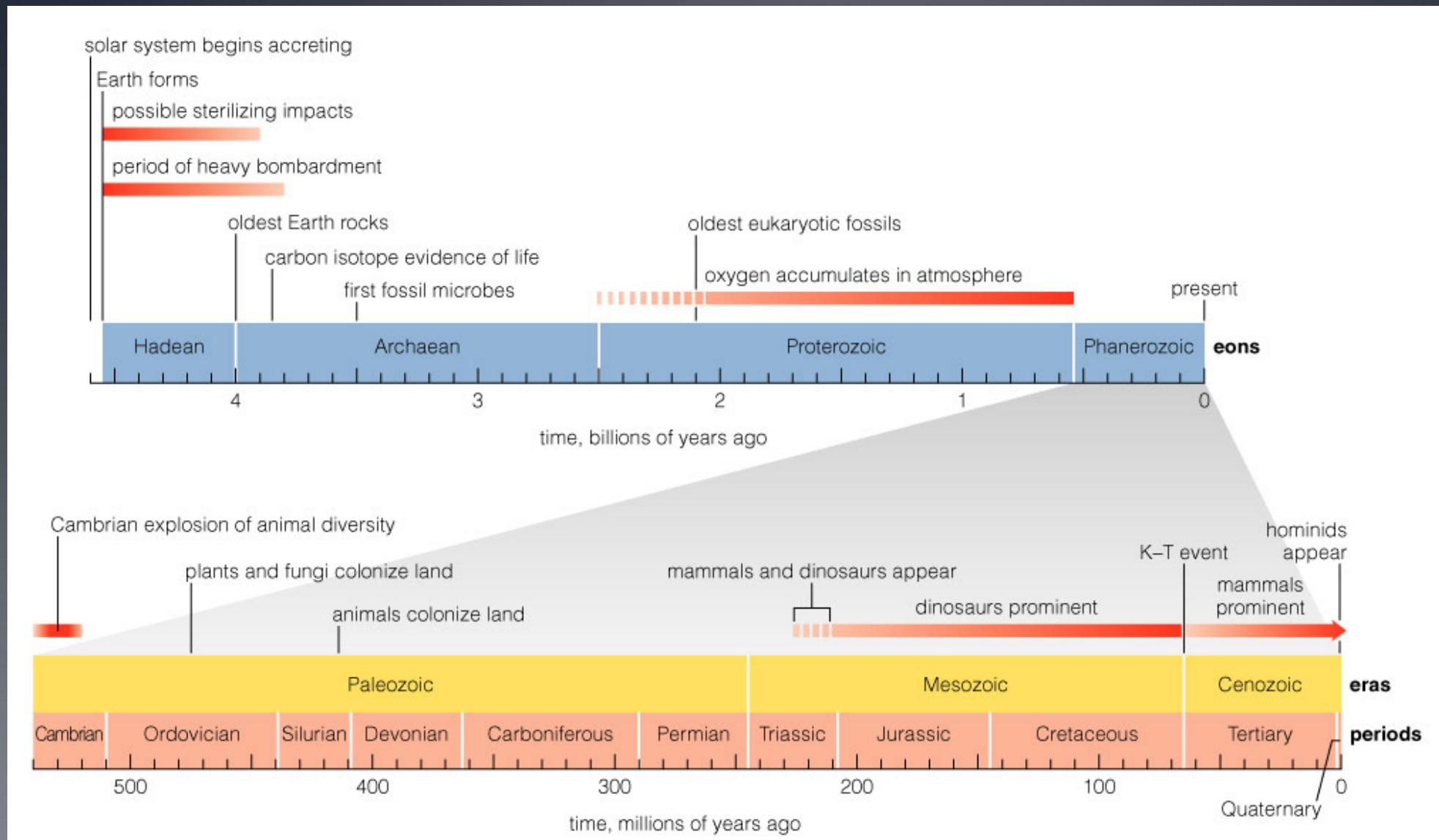


Tiny aquatic animals (0.5 mm)

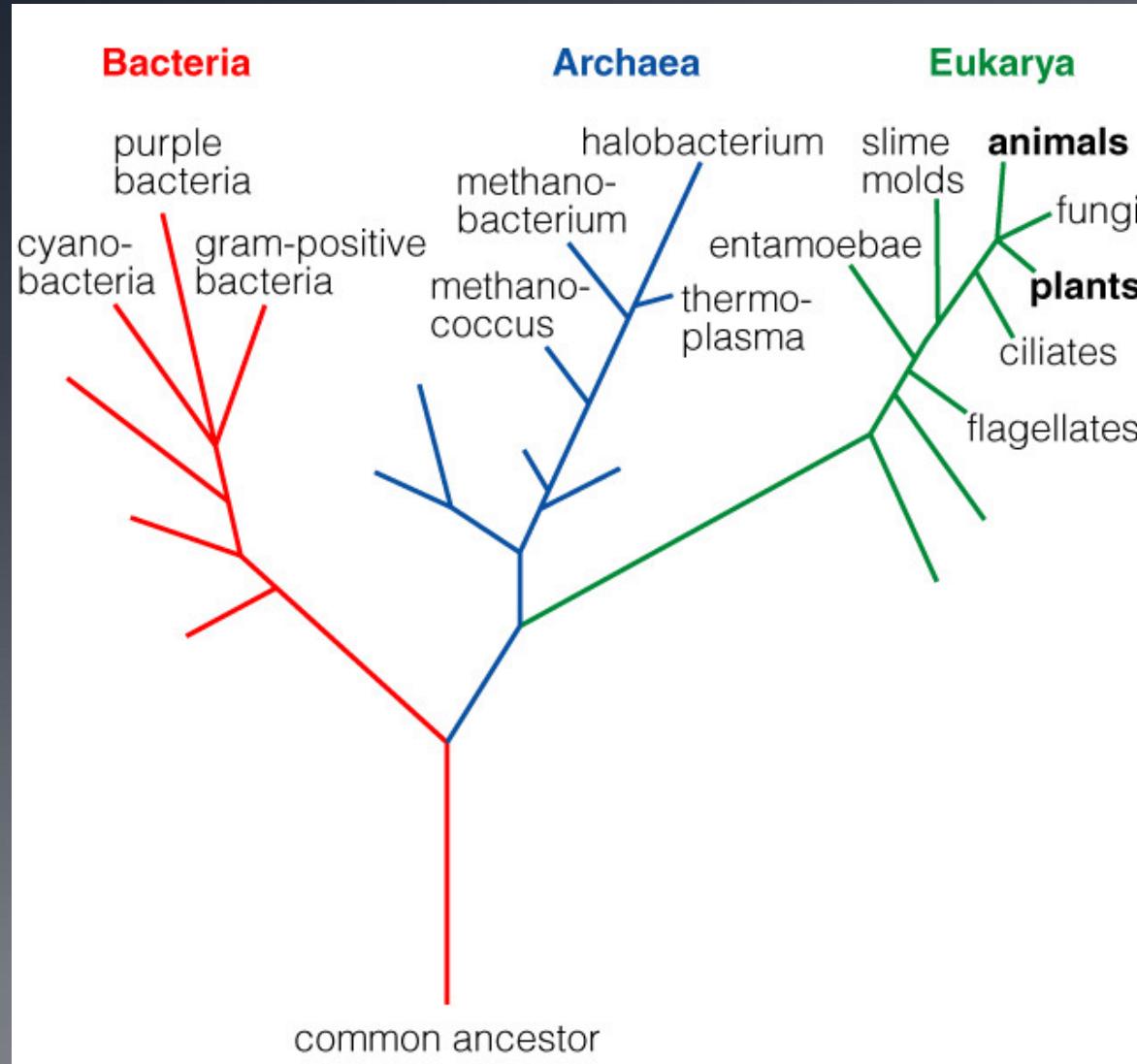
Survive in boiling water, near absolute zero

Survive in space

# When did life arise on Earth?

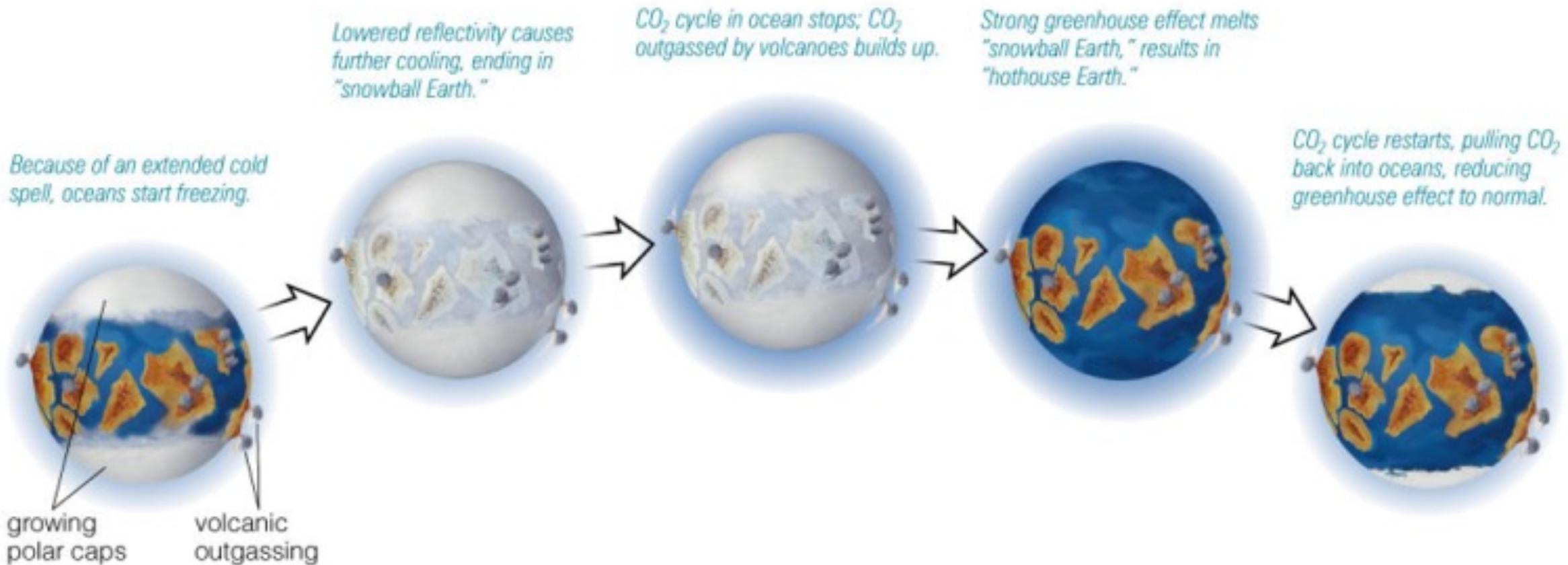


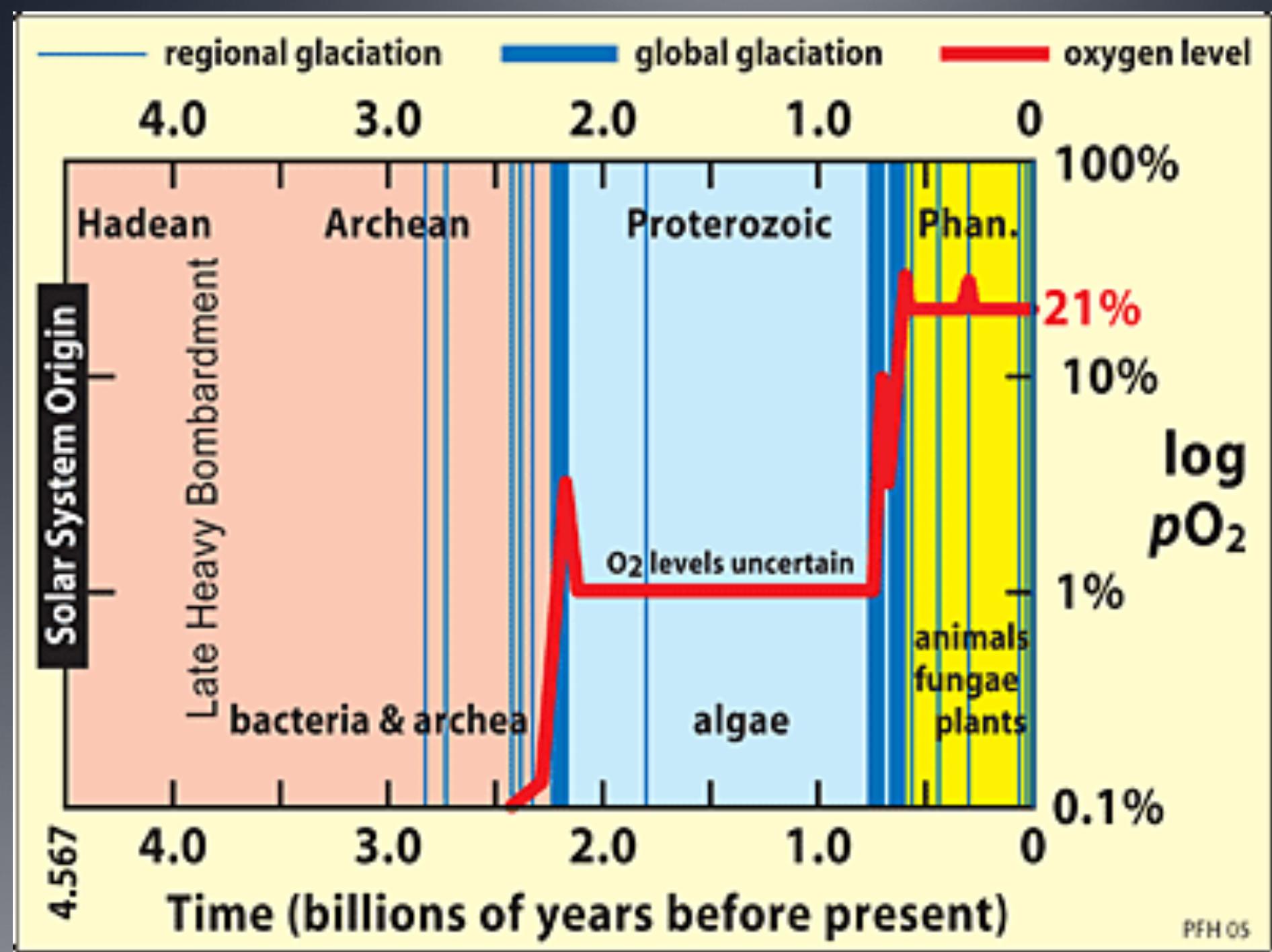
# Tree of Life



- Mapping genetic relationships has led biologists to discover this new “tree of life.”
- Plants and animals are a small part of the tree.
- Suggests likely characteristics of common ancestor.

# Five Stages of “Snowball” Earth





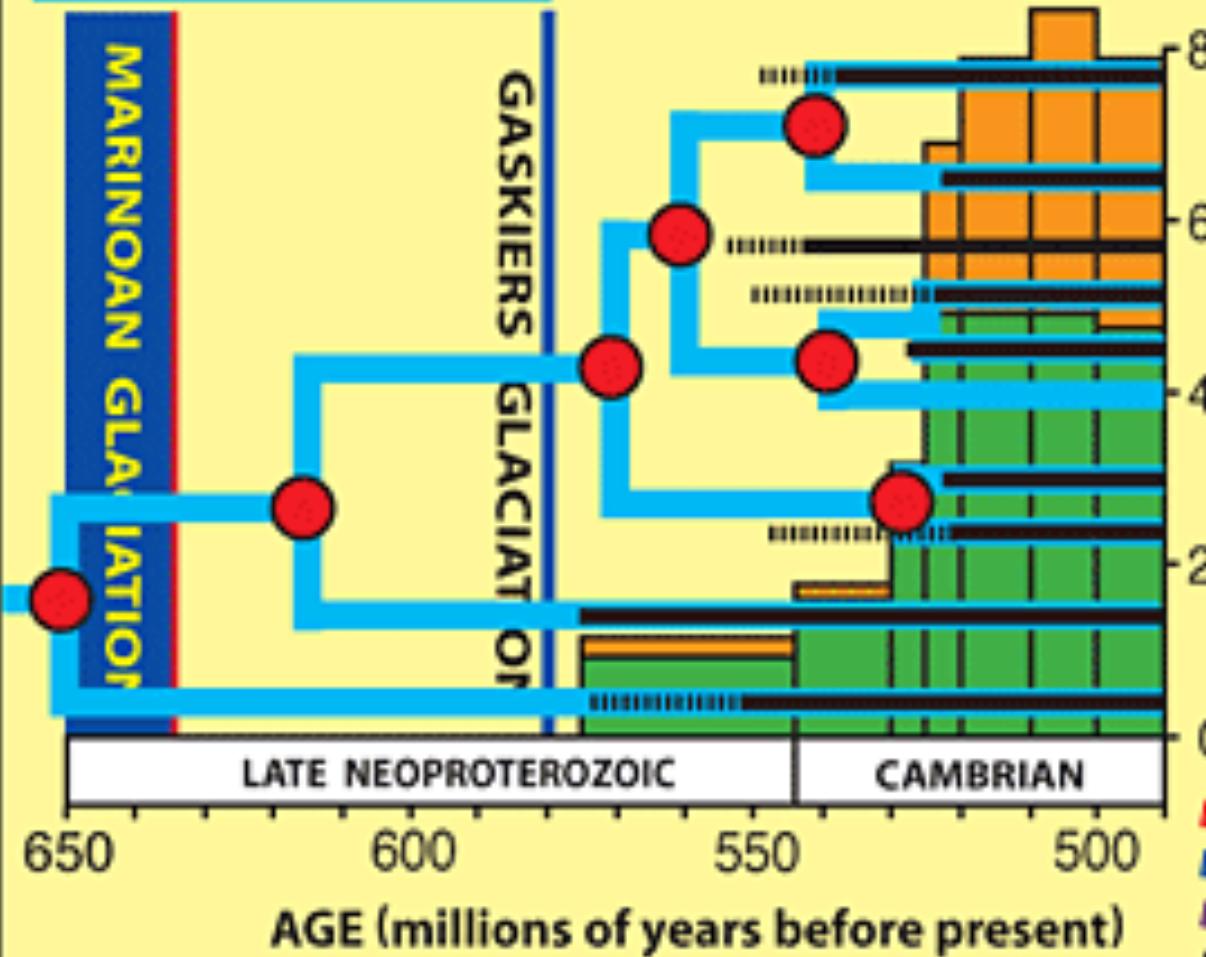
18S rDNA sequences  
(invertebrate calibrated)  
Peterson et al. (2004)  
PNAS 101, 6536-6541.

FOSSILS

..... stem groups  
— crown groups

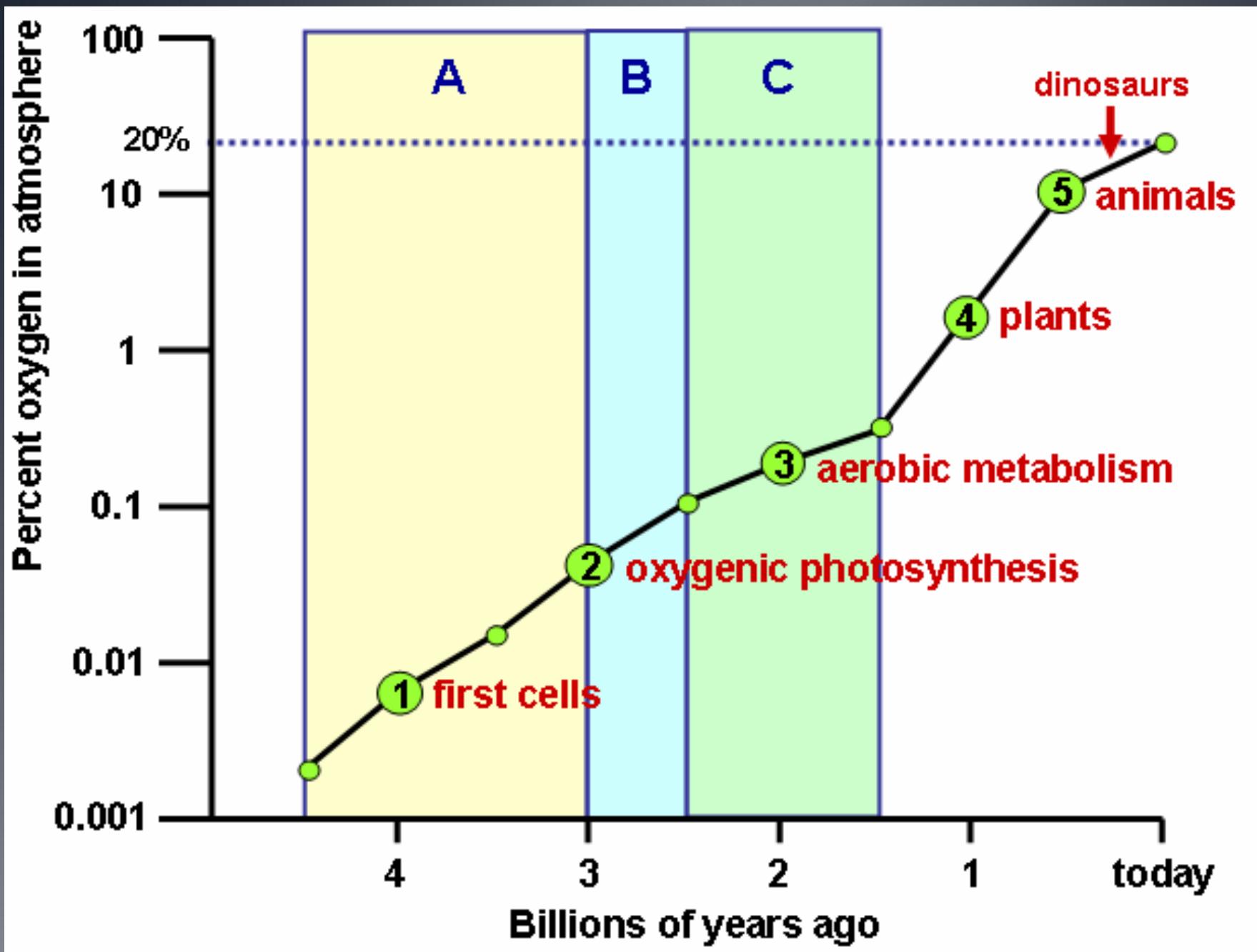
## Phyla

Arthropoda  
Nematoda  
*Priapula*  
Mollusca  
Annelida  
Brachiopoda  
Platyhelminthes  
  
Chordata  
Echinodermata  
Cnidaria  
Porifera  
  
**ECDYSOZOA**  
**LOPHOTROCHOZOA**  
**DEUTEROSTOMA**  
**DIPLOBLASTS**

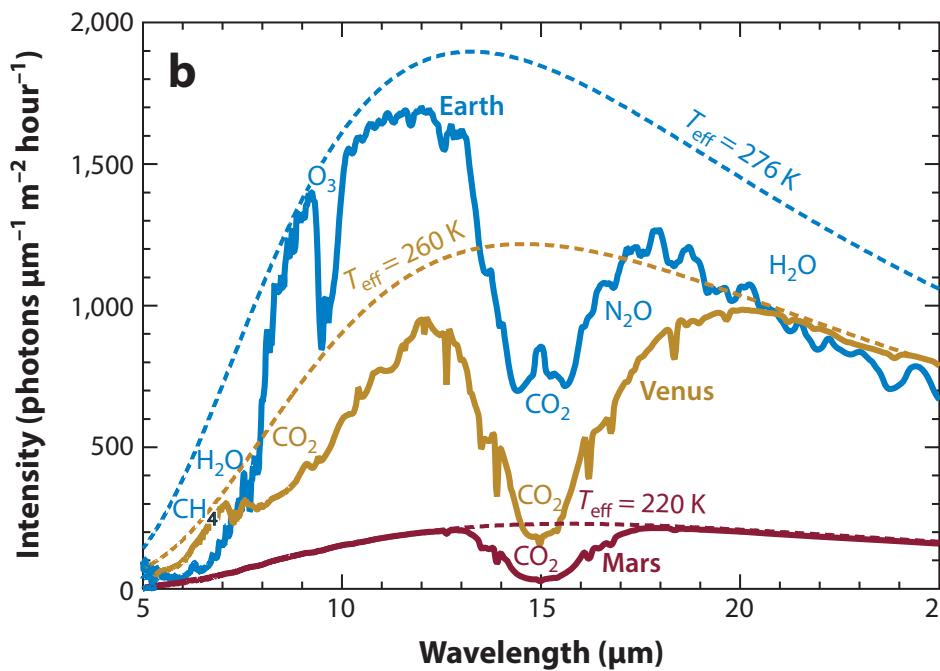
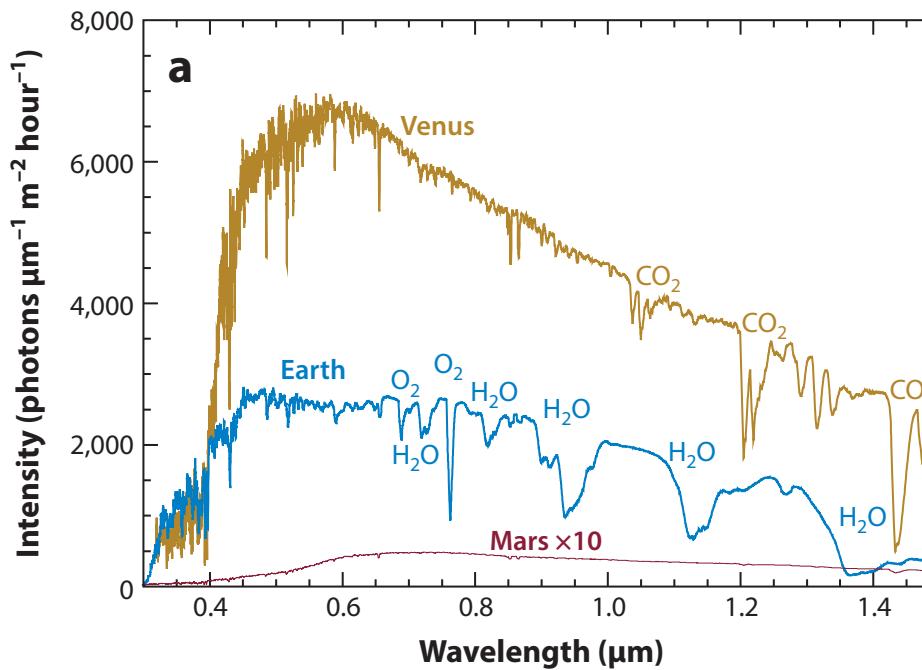


**EARLY ANIMAL DIVERSIFICATION**

modified from  
Knoll and Carroll  
(Science 284, 1999)



# Life changes its environment



- Life needs a suitable environment to flourish.
  - Feedback on environment/atmosphere
  - Changes: biosignature, a sign of the presence of life
- 
- Oxygen in Earth's atmosphere is a biosignature of life. Looking from afar, we cannot see plants and bacteria directly, but we can infer the presence of photosynthetic life if there is atmospheric oxygen.

# The Drake Equation

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Is intelligent life common?

# Fermi's paradox: where are the aliens?

## THE FLAKE EQUATION

[|<](#)[< PREV](#)[RANDOM](#)[NEXT >](#)[|>](#)

## THE FLAKE EQUATION:

FRACTION OF PEOPLE WHO  
IMAGINE AN ALIEN ENCOUNTER  
BECAUSE THEY'RE CRAZY OR  
WANT TO FEEL SPECIAL

PROBABILITY  
THAT THEY'LL  
TELL SOMEONE

AVERAGE NUMBER  
OF PEOPLE EACH  
FRIEND TELLS THIS  
"FIRSTHAND" ACCOUNT

FRACTION OF PEOPLE WITH  
THE MEANS AND MOTIVATION  
TO SHARE THE STORY WITH  
A WIDER AUDIENCE (BLOGS,  
FORUMS, REPORTERS)

$$P = W_p \times (C_r + M_i) \times T_k \times F_o \times F_f \times D \times A_v \approx 100,000$$

$(7,000,000,000)$      $(\frac{1}{10,000})$      $(\frac{1}{10,000})$      $(\frac{1}{10})$      $(10)$      $(10)$      $(\frac{1}{10})$      $(\frac{1}{100})$

WORLD  
POPULATION

FRACTION OF PEOPLE WHO  
MISINTERPRET A PHYSICAL  
OR PHYSIOLOGICAL EXPERIENCE  
AS AN ALIEN SIGHTING

AVERAGE  
NUMBER  
OF PEOPLE  
THEY TELL

PROBABILITY THAT ANY  
DETAILS NOT FITTING THE  
NARRATIVE WILL BE REVISED  
OR FORGOTTEN IN RETELLING

EVEN WITH CONSERVATIVE GUESSES FOR THE VALUES OF THE VARIABLES, THIS SUGGESTS THERE MUST BE A HUGE  
NUMBER OF CREDIBLE-SOUNDING ALIEN SIGHTINGS OUT THERE, AVAILABLE TO ANYONE WHO WANTS TO BELIEVE!

# Fermi's paradox: where are the aliens?

Three general groups of answers

- We are alone (rare Earth theory)
- Interstellar travel is not possible
- An extraterrestrial policy of non-intervention





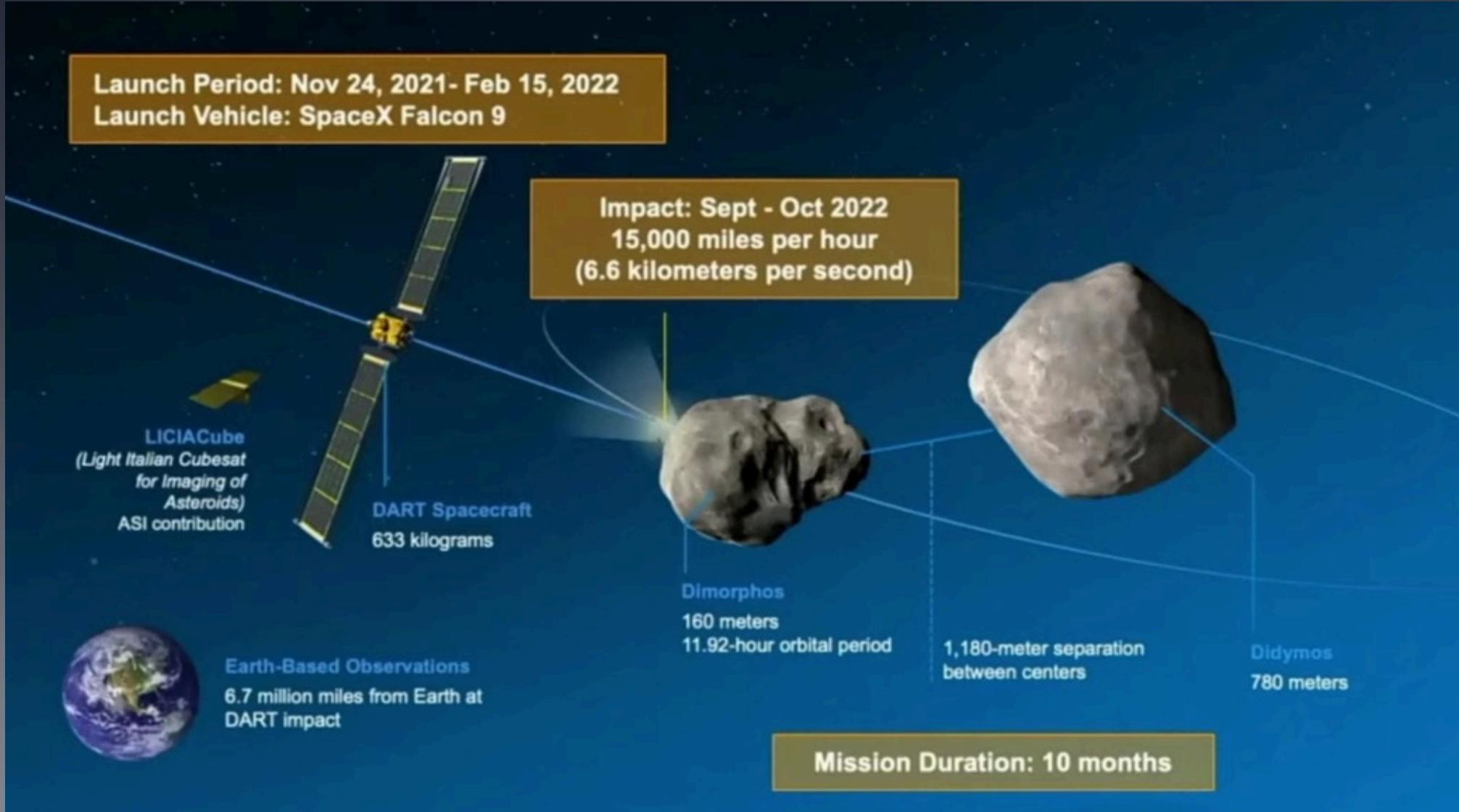
Tunguska event (Siberia, Russia, 1908)  
trees knocked down across 2000 km<sup>2</sup>!

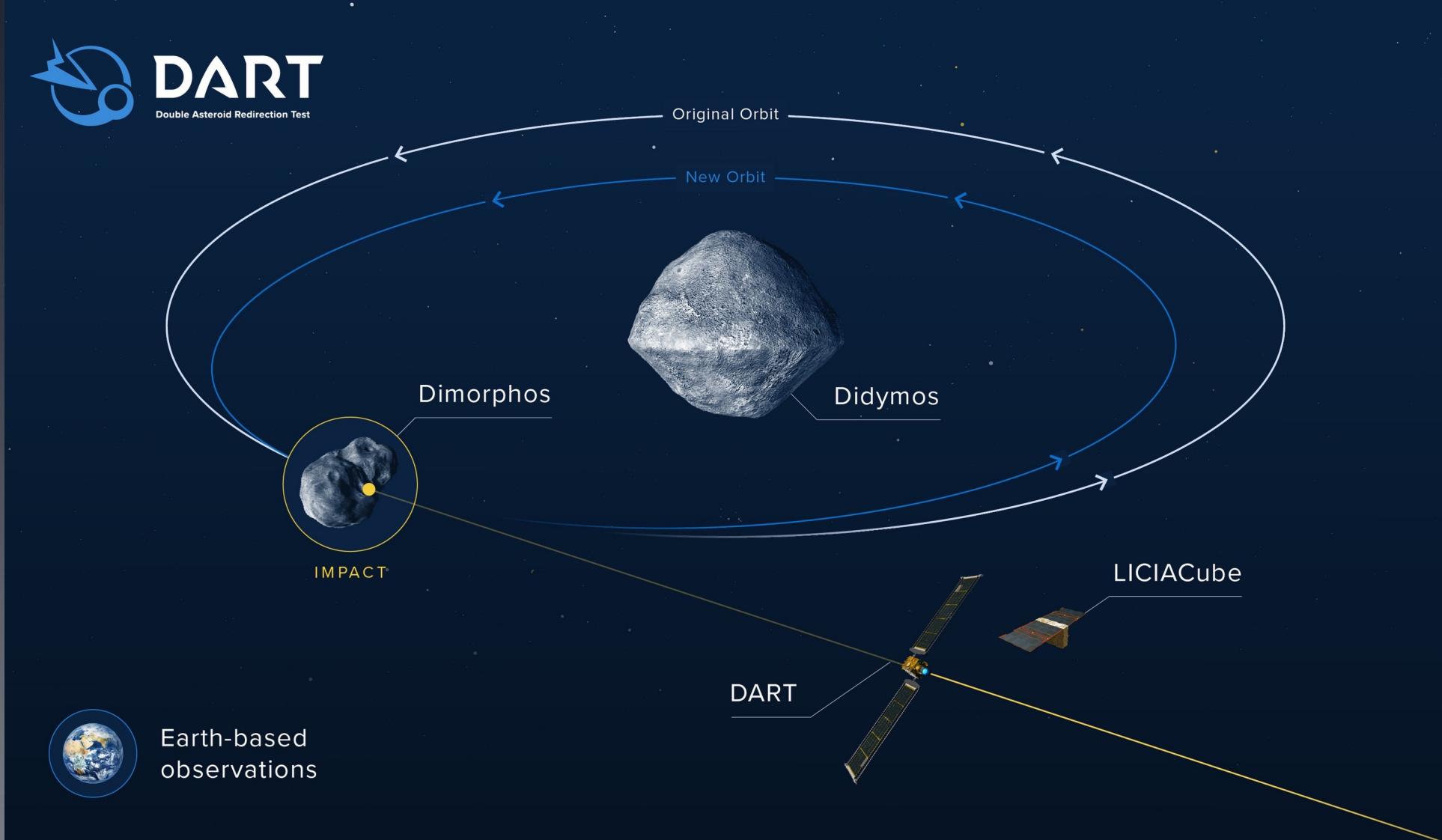


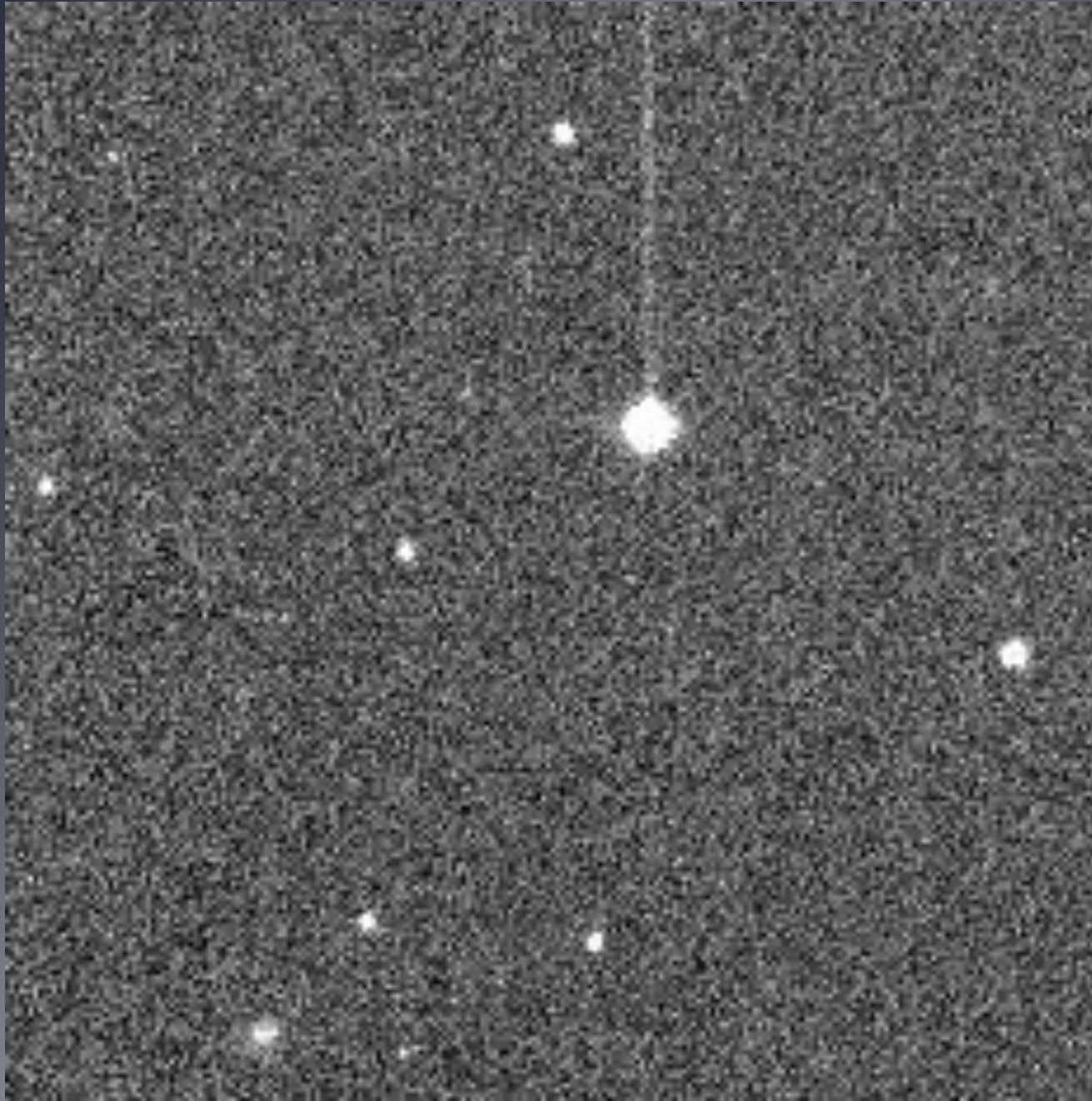
Photo from 1929

# DART mission

- Double Asteroid Redirection Test (DART) Mission





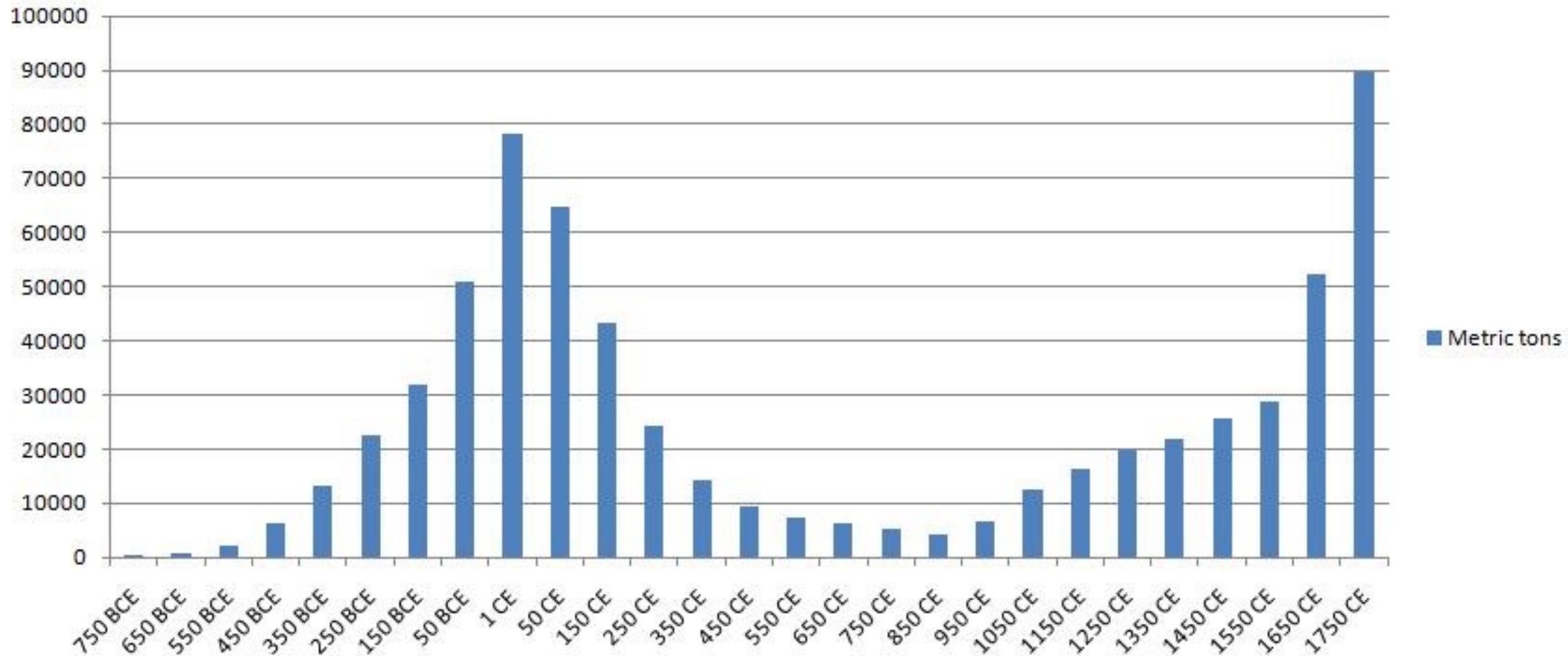


# US nuclear weapons test, Bikini Atoll



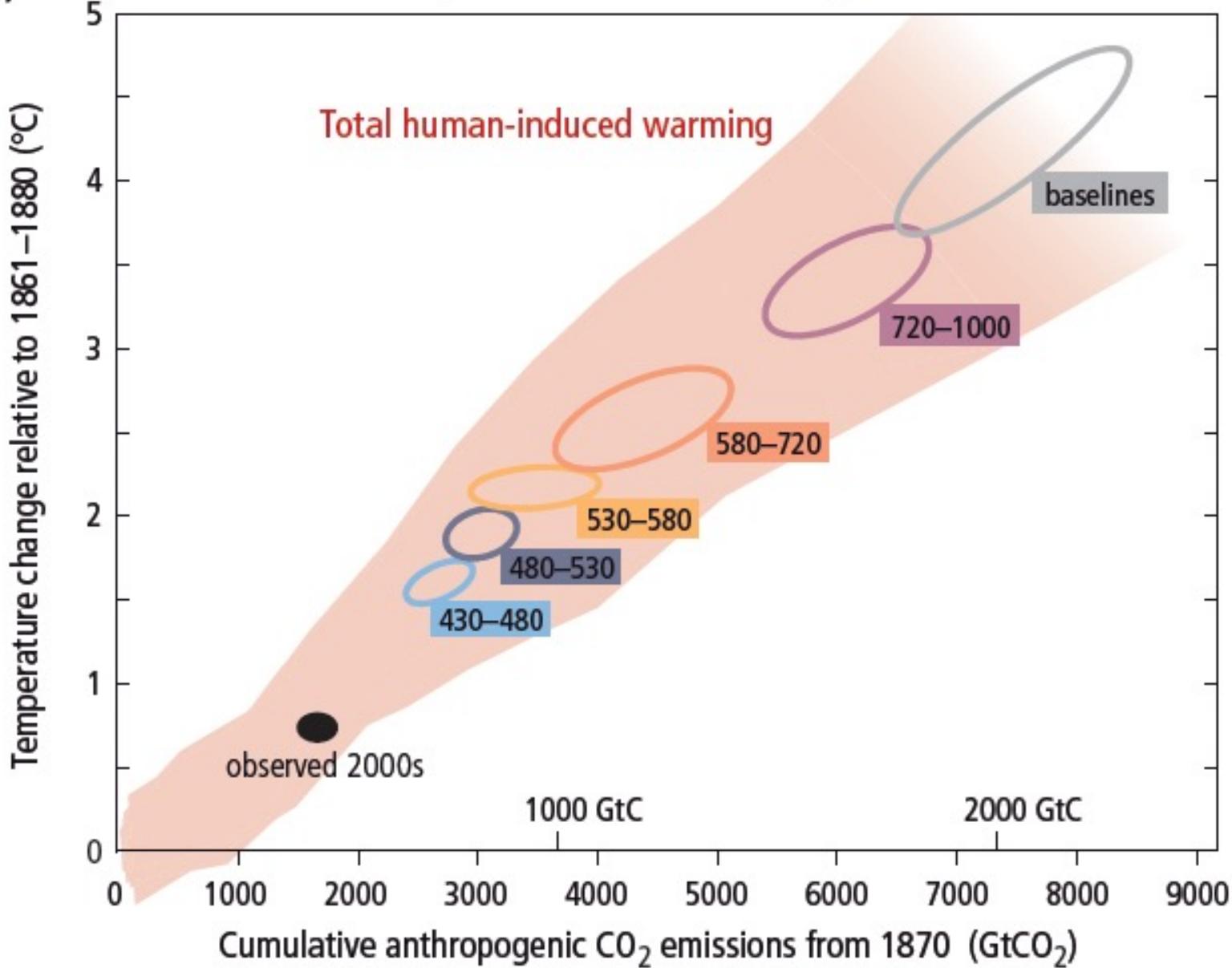
# Societal collapse: Rome

## World Lead Production



(b)

## Warming versus cumulative CO<sub>2</sub> emissions



# What is our future?

Stephen Hawking: “We are running out of space and the only places to go to are other worlds. It is time to explore other solar systems. Spreading out may be the only thing that saves us from ourselves. I am convinced that humans need to leave Earth.”

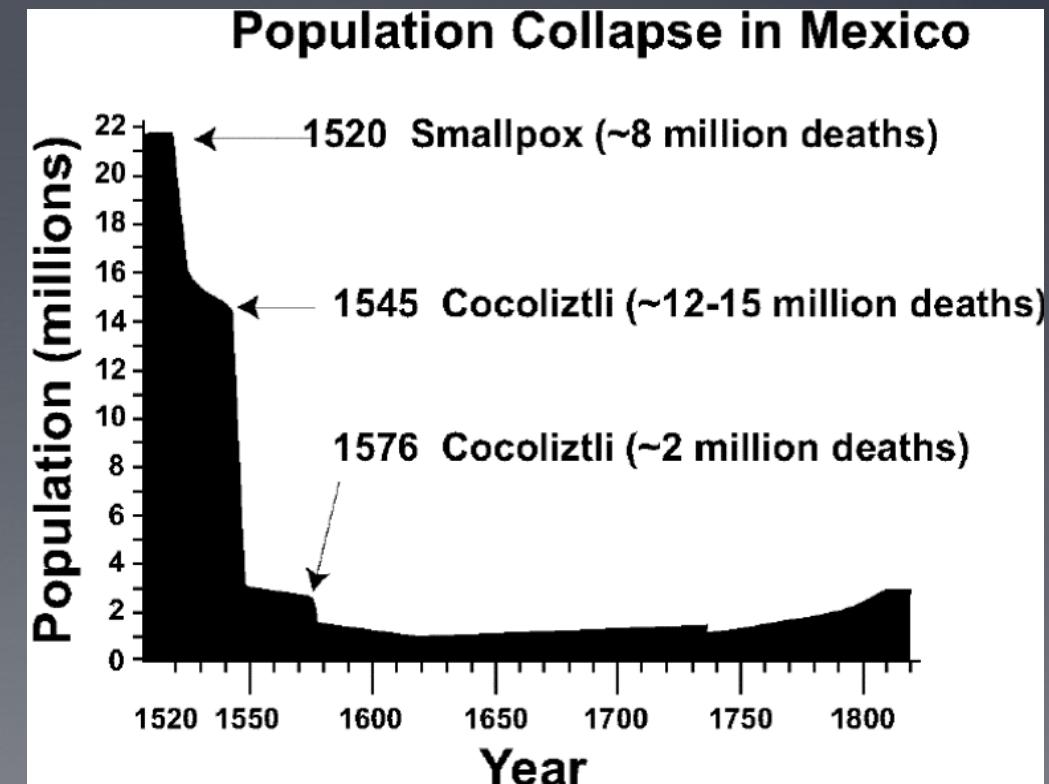


Elon Musk: “Either we spread earth to other planets, or we risk going extinct. An extinction event is inevitable and we're increasingly doing ourselves in. The goal [of SPACEX] is to improve rocket technology and space technology until we can send people to Mars and establish life on Mars.”



# "To serve man"

- History of inter- and intra-species interactions is not great



# “To serve man”



Stephen Hawking: “As I grow older I am more convinced than ever that we are not alone. If so, they will be vastly more powerful and may not see us as any more valuable than we see bacteria.”

# Is a search for biomarkers correct?

If we succeed as a species, we will spread across the nearby galaxy

But... it will be machines, not us



She's an alien from outer space, she's a cyber girl without a face.



# Life in the Universe

- Does life exist? biggest solvable question
  - Many books and movies: how would we respond to intelligent life?
  - Science Fiction: often statements about our own world
  - We might want to avoid it
- Scientific searches:
  - biomarkers on exoplanets
  - fossil record on Mars
  - Subsurface oceans on Enceladus, Europa
  - (SETI)
- How do we get off our planet?
  - And protect ourselves from comets and asteroids!

