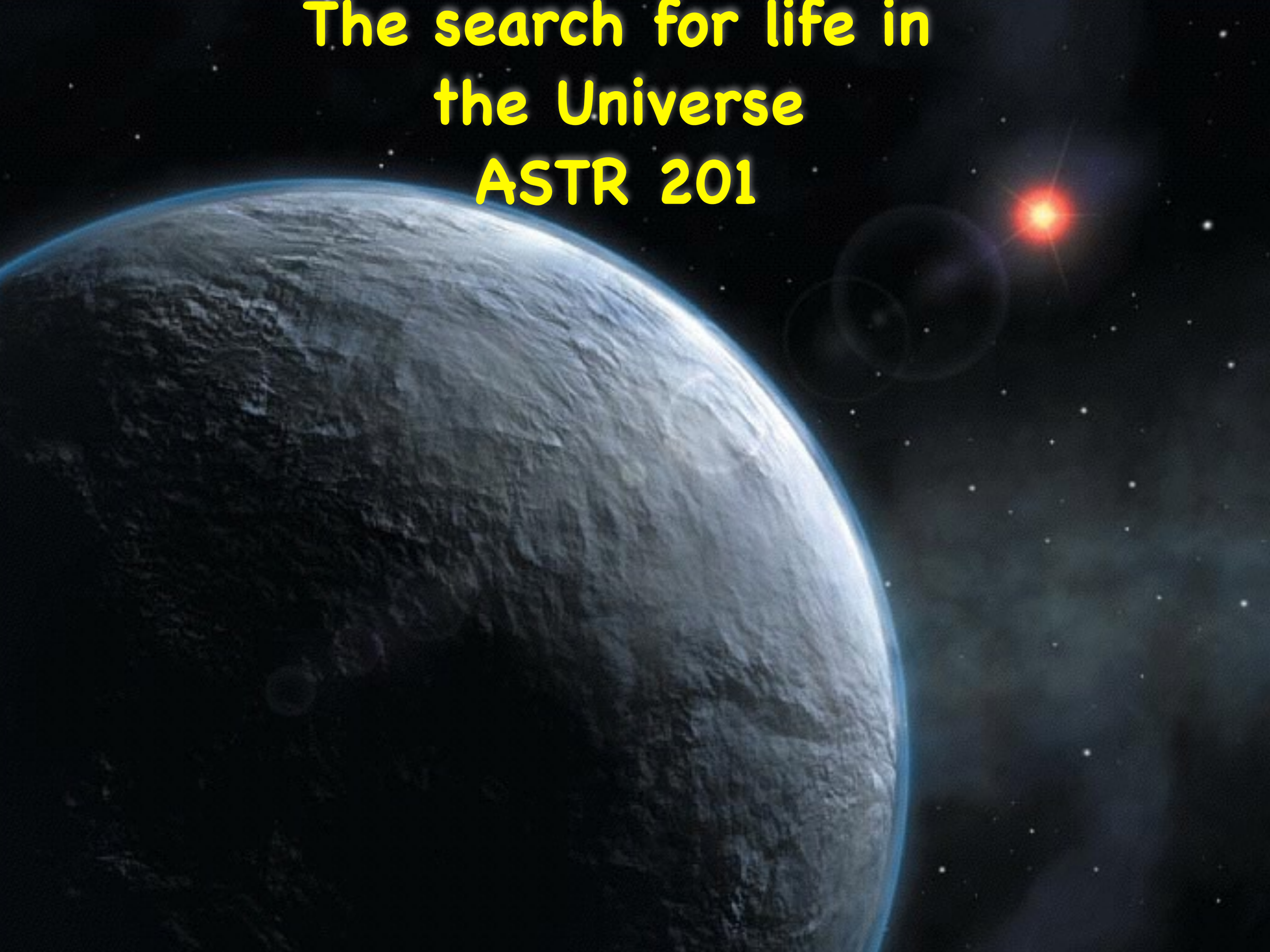
The search for life in the Universe
ASTR 201



Outline of today's class

- Review of course syllabus.
- Introduction to Astrobiology.
- Overview of topics to be covered during this course.

Astronomy 201: The search for life in the Universe
Section A01, Fall 2019

Jon Willis, Elliot 211, Tel. 721-7740, email: jwillis@uvic.ca

Website for lecture notes and assignments: http://www.astro.uvic.ca/~jwillis/Jon_Willis_Teaching.html

Lectures: ECS 124, Tuesday, Wednesday, Friday 9.30-10.20am.

Office hours: Monday 2.00-4.00pm.

Course text: Life in the Universe by Bennett and Shostak (4th Ed.)

Course outline: A general science course designed to be accessible to students not majoring in science. An overview of modern scientific thought on the possibility of life beyond Earth and the current research being done to find it; the likeliest locations of life in our Solar System; the hunt for planets around other stars; the search for extraterrestrial intelligence (SETI). Laboratories on alternate weeks; practical work includes observations with campus telescopes.

Course assessment:
Assignments: 10%
Lab: 25%
Mid-term: 25%
Final: 40%

A minimum grade of 50% in the laboratory component is required to pass the course.

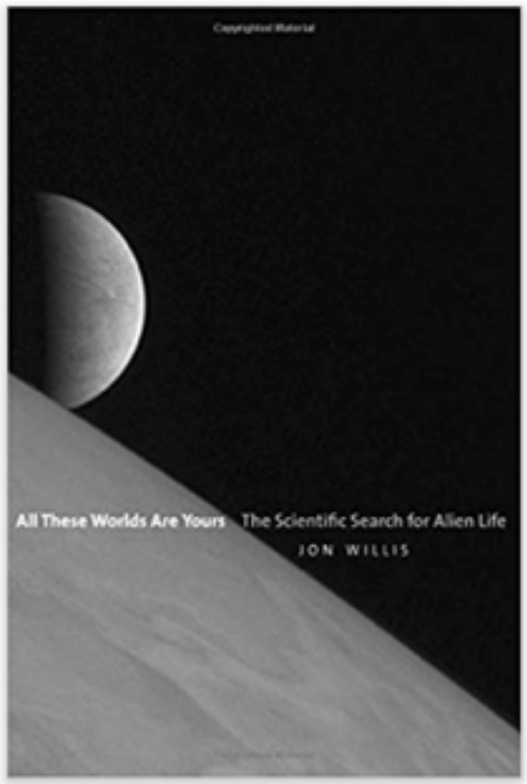
Approximately six assignments will be issued through the semester. Assignments will typically be due one week after the issue date. Late assignments will not be accepted.

All These Worlds Are Yours: The Scientific Search for Alien Life

by Jon Willis (Author)

9 customer reviews

Look inside



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The search for life in the Universe

- At present, there is no scientific evidence that life exists anywhere in the universe except for Earth.
  - we will review what qualifies as scientific evidence.
  - for now, we will note simply that there is a strong consensus among the world's scientists that no such evidence has yet been found.
- It is possible that this is because life does not exist anywhere in the universe except for Earth.
- However, it is more likely that we simply have not been able to find it yet.

Astrobiology

- Given that we have not yet found life beyond Earth, the search for such life is likely to be challenging
  - waiting for it to appear on our doorstep doesn't seem to work!
  - simply pointing telescopes at the sky hasn't been successful either
  - clearly there is a need for good strategies in deciding how best to increase our chances of finding life elsewhere
- The science of Life in the Universe is called Astrobiology
- The primary goals of astrobiology include
  - understanding the conditions necessary for life on Earth (and possibly the conditions required for life in general)
  - looking for places in the universe which have these conditions
  - trying to actually detect extraterrestrial life

Fields related to astrobiology

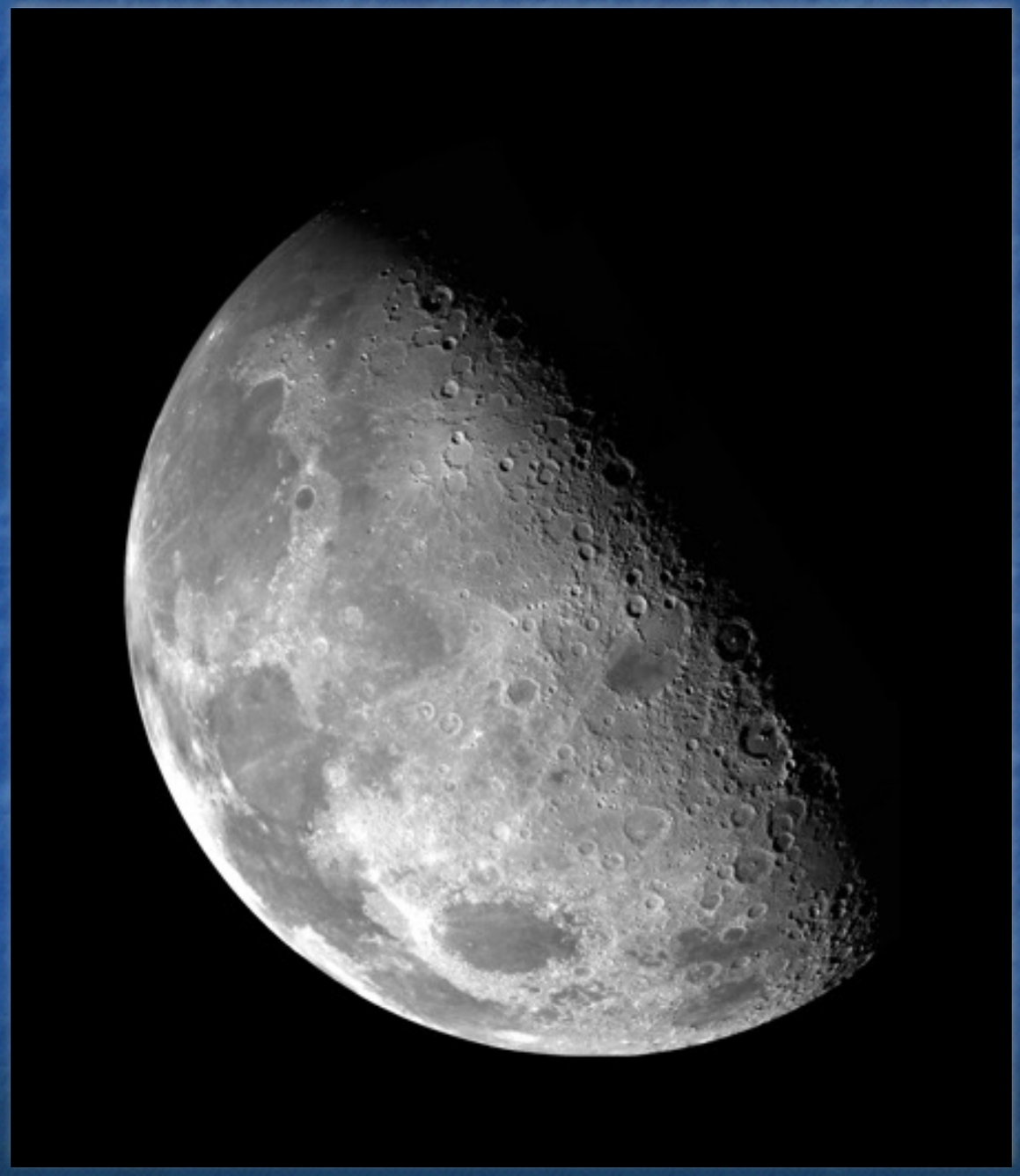
- Astronomy
- Biology
- Planetary science
- Geology
- Physics
- Chemistry
- Mathematics
- Statistics
- Computer science
- Philosophy
- …

Is Earth the only "world"?

- Earth was long thought to be the only "world"
- For thousands of years, the five naked-eye planets have been known
  - Mercury, Venus, Mars, Jupiter, and Saturn
- However, the nature of these objects was largely unknown until the advent of the telescope

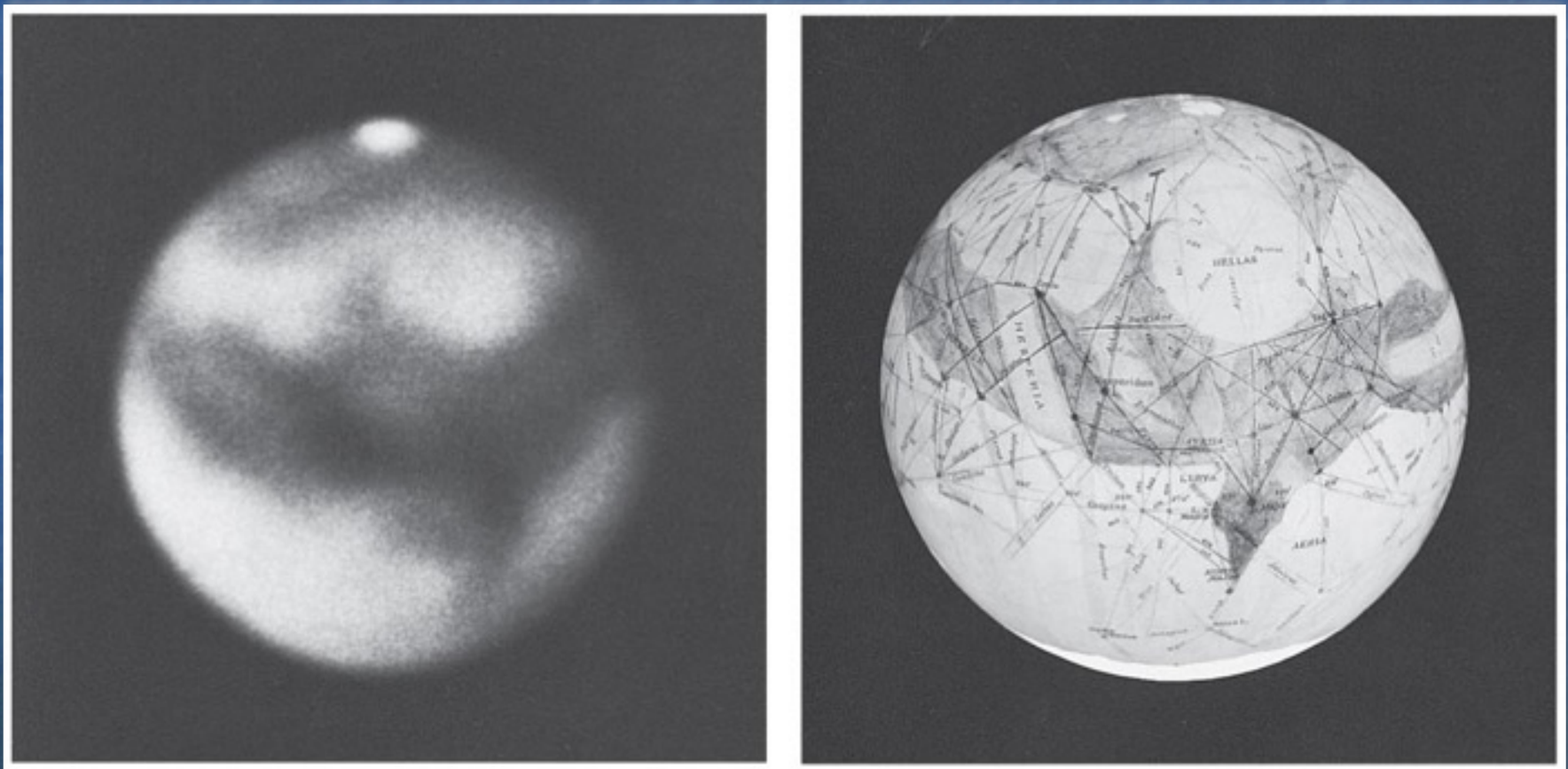
The Moon as another world

- In 1609, Galileo showed that the Moon is a world with mountains, valleys, craters, etc.
- He also speculated that the lunar maria might be oceans of water
- Kepler suggested that the Moon had an atmosphere and inhabitants!



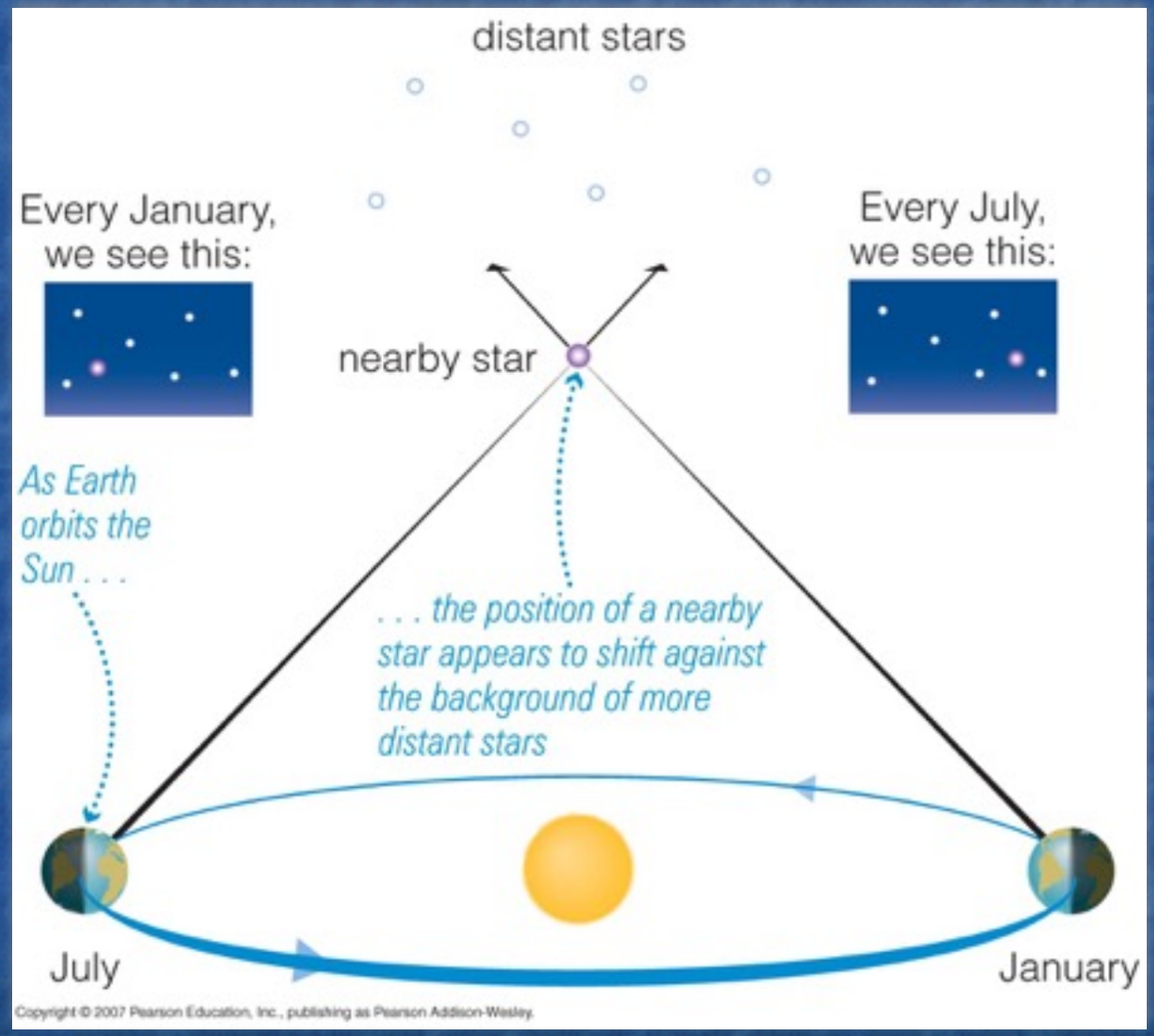
Percival Lowell's Mars

- In the late 1800's, astronomer Percival Lowell made detailed maps of Mars, identifying numerous "canals"
- He concluded that a Martian civilization had made these canals to transport water from the poles to cities close to the equator



Are there other suns?

- Ancient astronomers speculated that stars were like the Sun but much further away
- Confirmation of this idea required measurement of stellar distances
- One technique for measuring distances is called stellar parallax



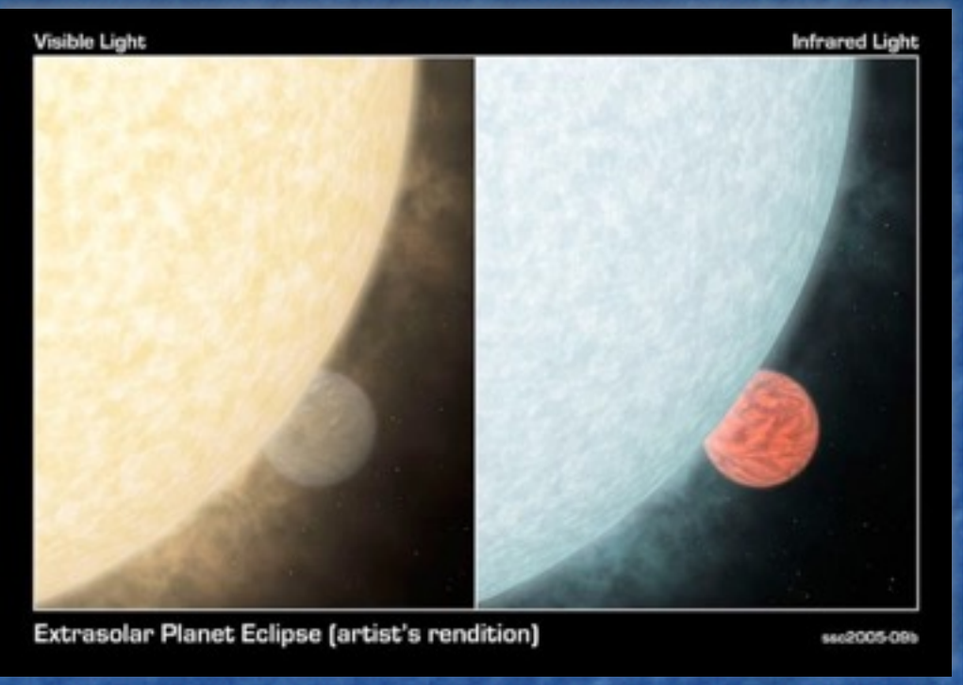
The first detections of stellar parallax

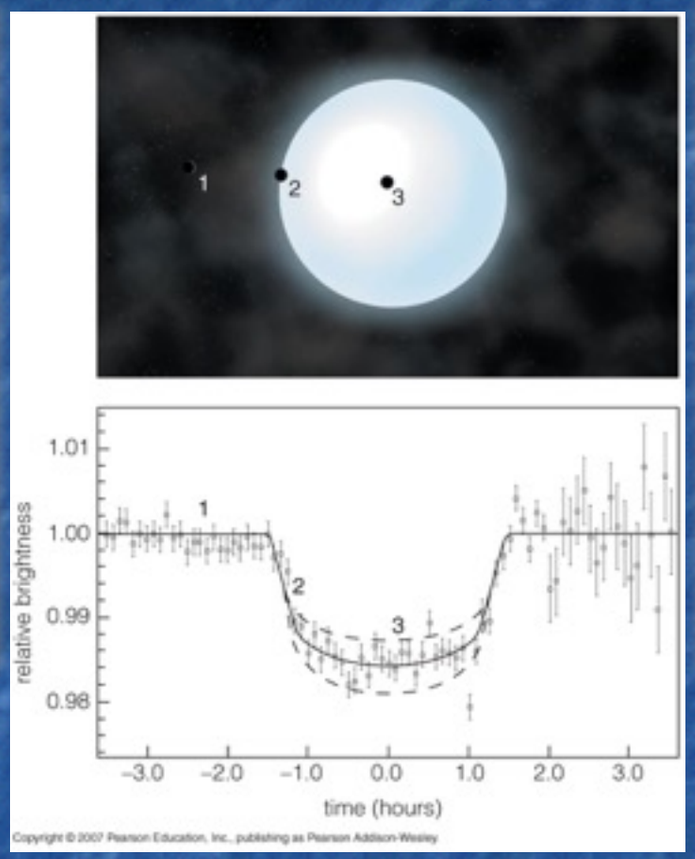
- Ancient astronomers tried to detect stellar parallax with the naked eye, but were unsuccessful
- In 1838, Friedrich Bessel became the first to measure the parallax of another star (61-Cygni)
  - he found a parallax of 0.3 arcseconds, corresponding to a distance of about 700,000 AU! (11 LY)
  - later in 1838, Thomas Henderson measured a parallax of 0.76" for Alpha Centauri, placing it only 270,000 AU away (4.3 LY)

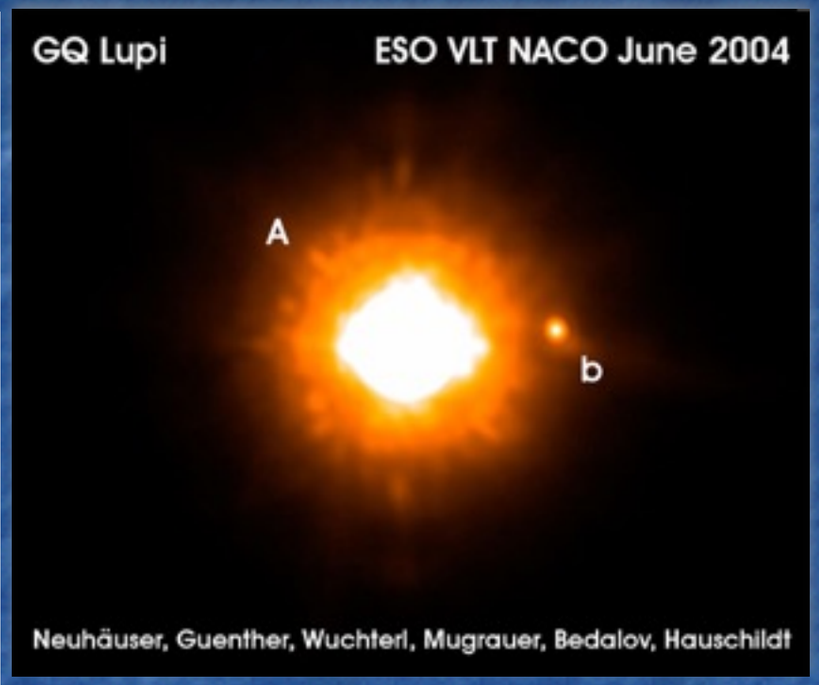
Do other stars have planets?

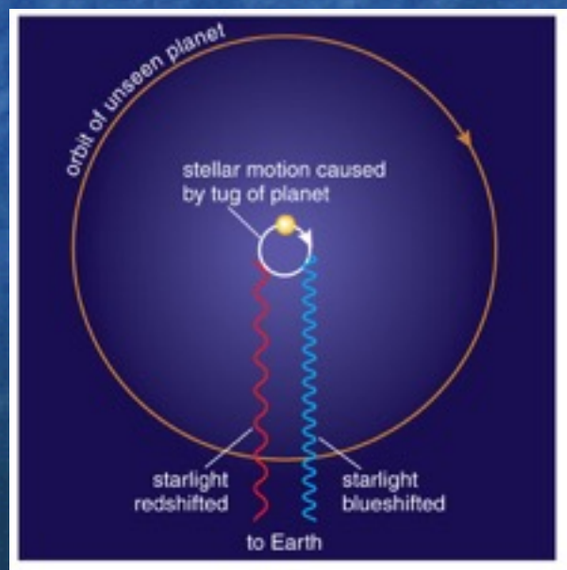
- Given that the Sun is a fairly ordinary star, it seems reasonable to imagine that other stars may have planets too
- However, it is extremely difficult to detect a (relatively) small, faint planet very close to a bright star
- Despite several decades of effort, no so-called extra-solar planets had been detected as of the early 1990's
- However, the first such planet (51 Pegasi) was detected in 1995
- We now know of 3706 extra-solar planets!

Techniques for finding extra-solar planets

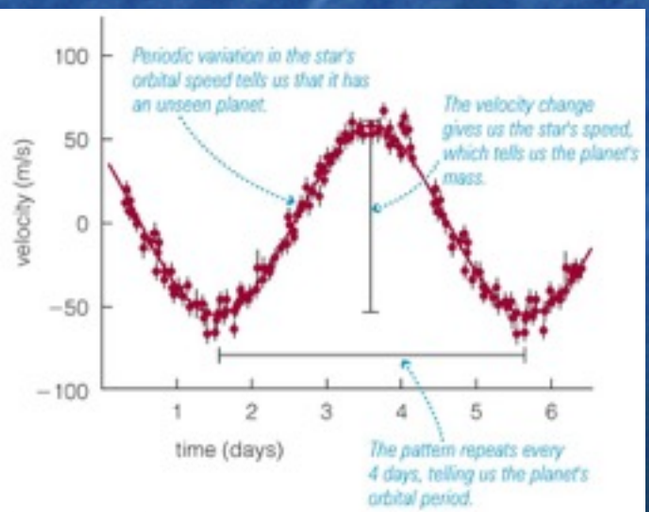




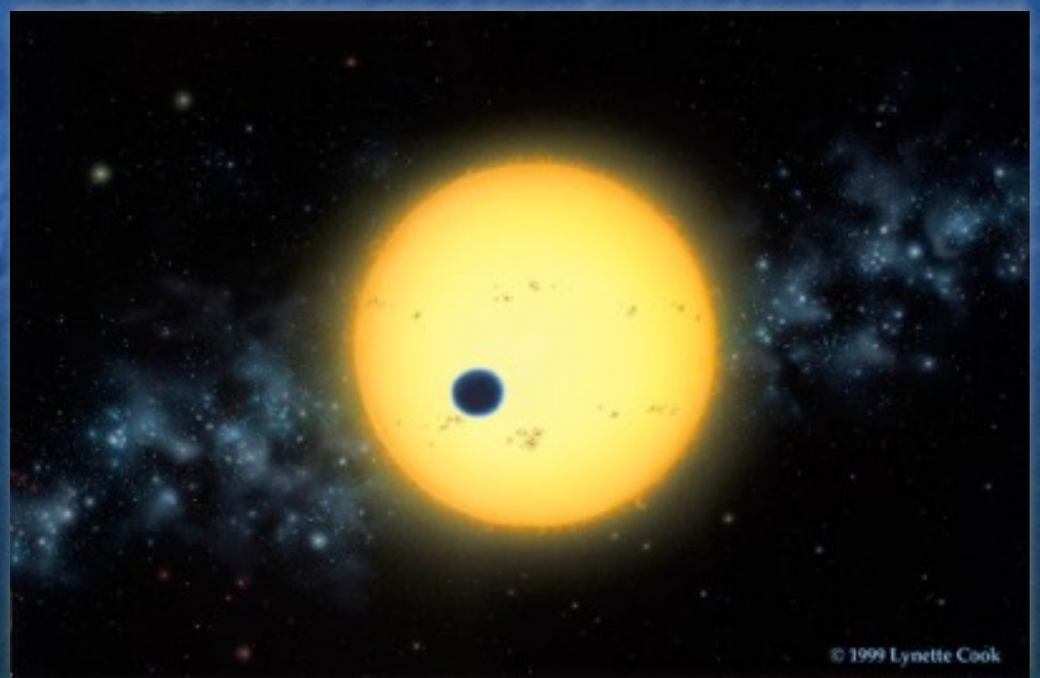




a Doppler shifts allow us to detect the slight motion of a star caused by an orbiting planet.



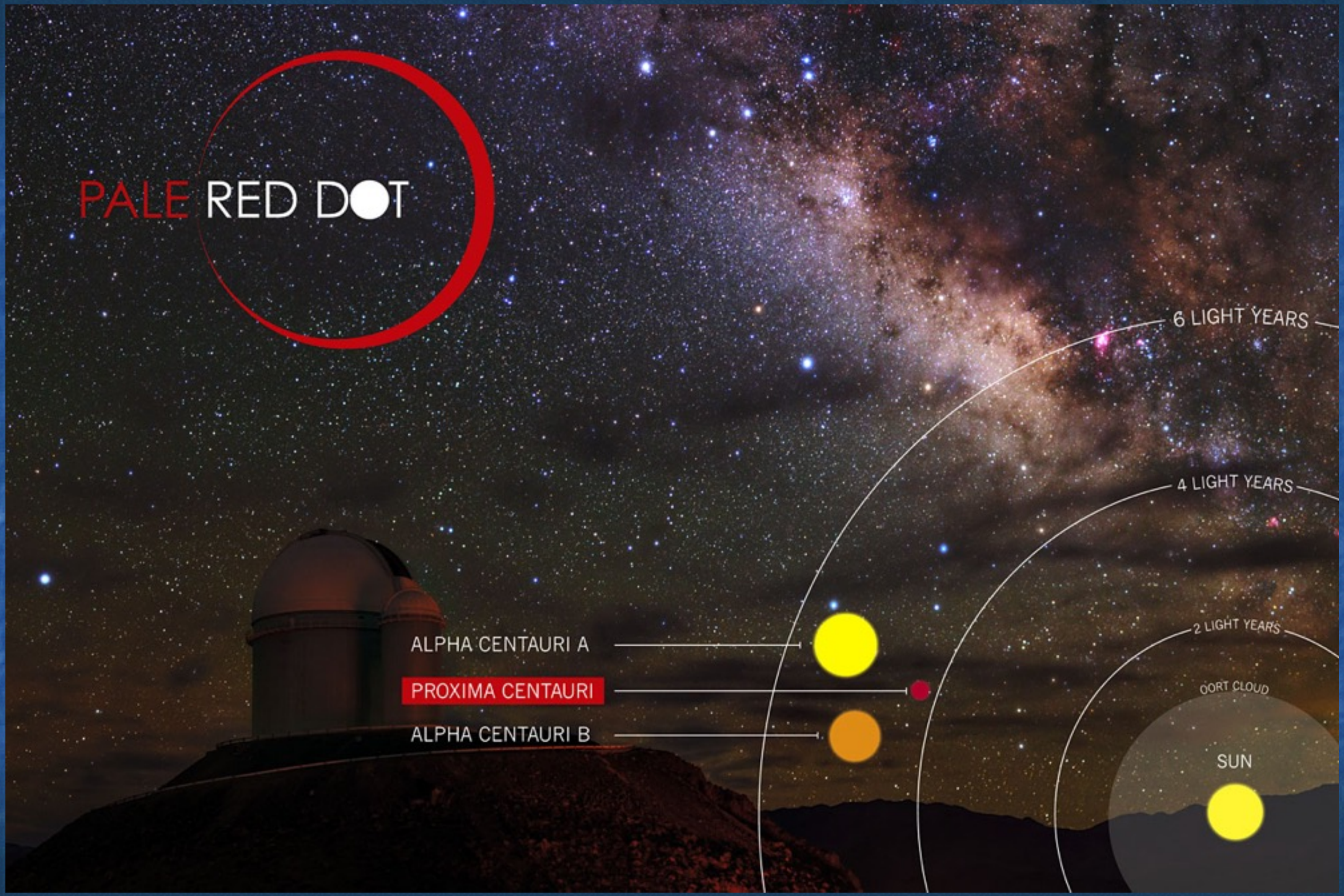
b A periodic Doppler shift in the spectrum of the star 51 Pegasi shows the presence of a large planet with an orbital period of about 4 days. Dots are actual data points; bars through dots represent measurement uncertainty.



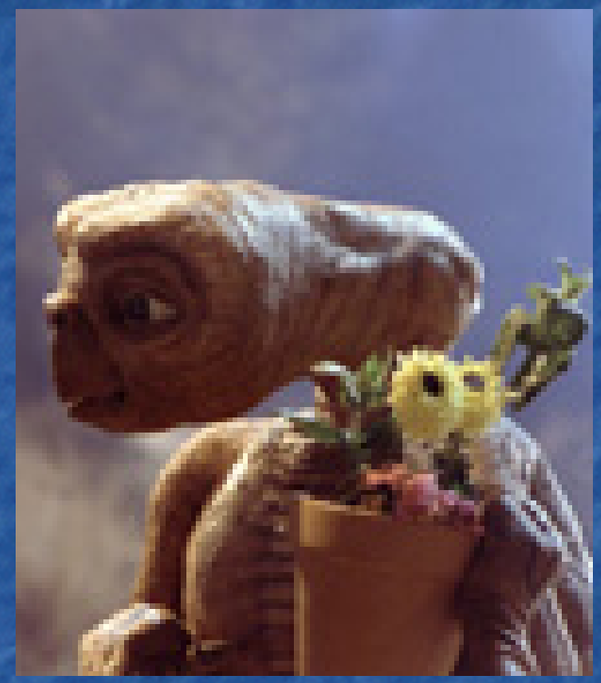
How many planets are there in the observable Universe?

- We will make a very rough estimate of the number of planets in the observable universe, and for the sake of argument, let's be very pessimistic ...
  - assume that 1% of stars have planets (likely about 1-30%)
  - assume that each of these stars has only 1 planet
  - assume our Galaxy contains 100 billion stars
    - more likely 200-400 billion
  - assume the observable universe contains 100 billion galaxies
    - likely to be considerably higher
- Together, this implies that the observable universe contains 100 billion * 100 billion * 1 * 0.01 planets
  - 100 billion billion planets in total (10^{20})
- While this calculation is overly simplistic, there clearly is no shortage of locations in which life may exist!

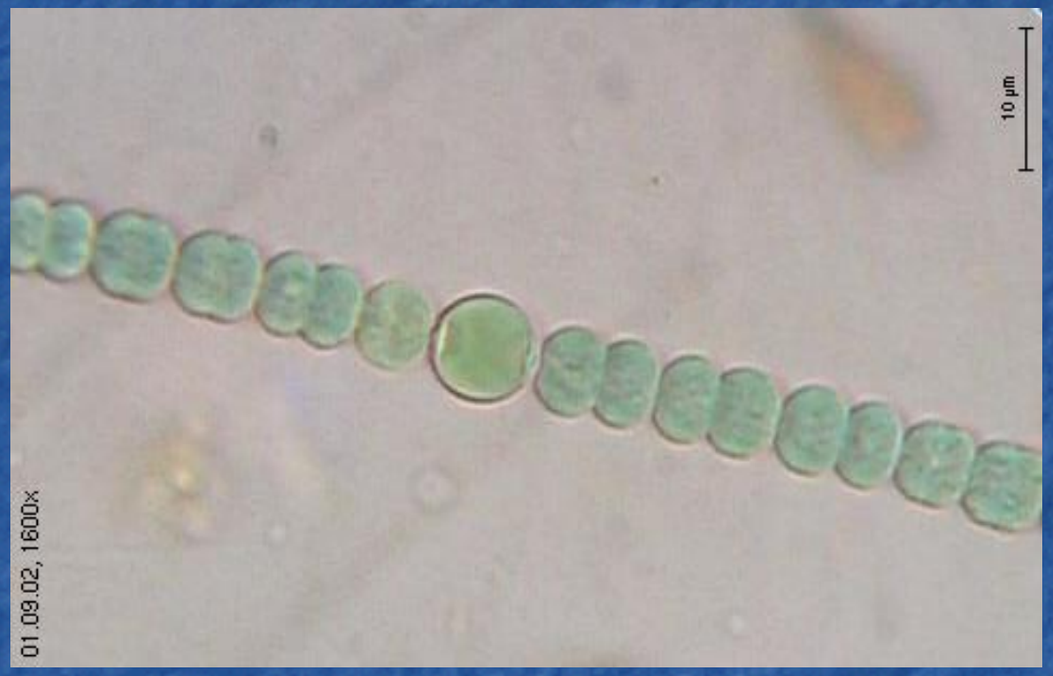
PALE RED DOT

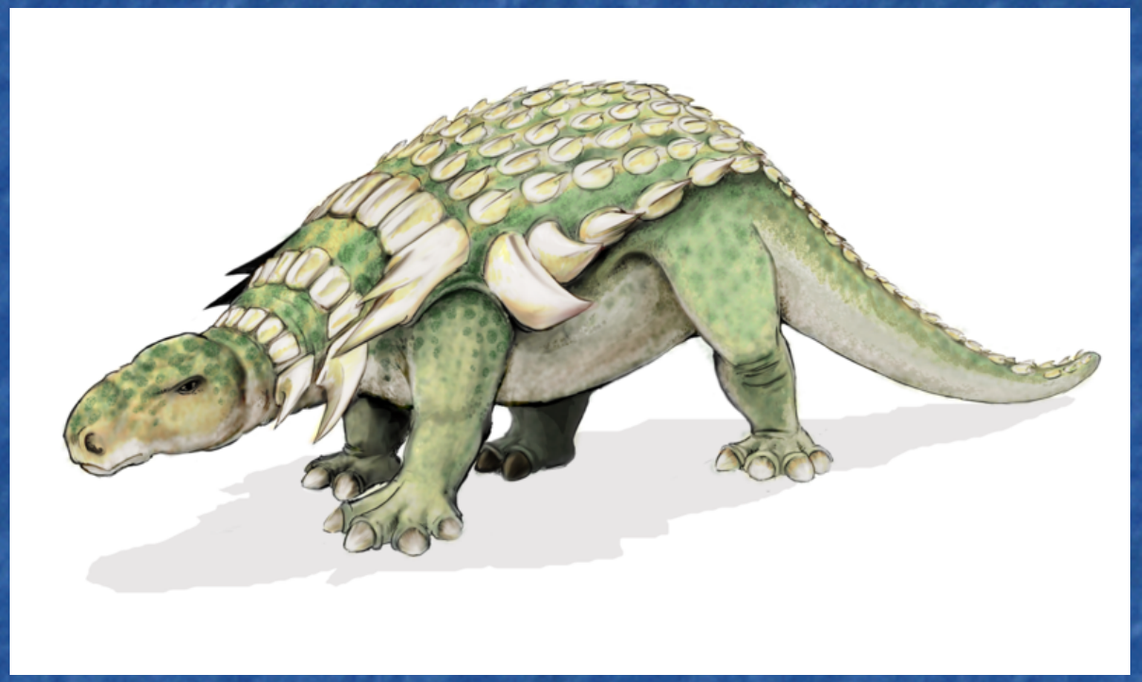

6 LIGHT YEARS
4 LIGHT YEARS
2 LIGHT YEARS
OORT CLOUD
SUN
ALPHA CENTAURI A
PROXIMA CENTAURI
ALPHA CENTAURI B

Is this what extra-terrestrial life looks like?



A wider variety of possibilities …





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Where will we discover new life?

- In a test tube?
- Bacterial goo on Titan?
- Biomarkers in an exoplanet atmosphere?
- Calling us up on an interstellar laser phone?

When will we discover new life?

- Next 10 years?
- Next 100 years?
- Next 1000 years?

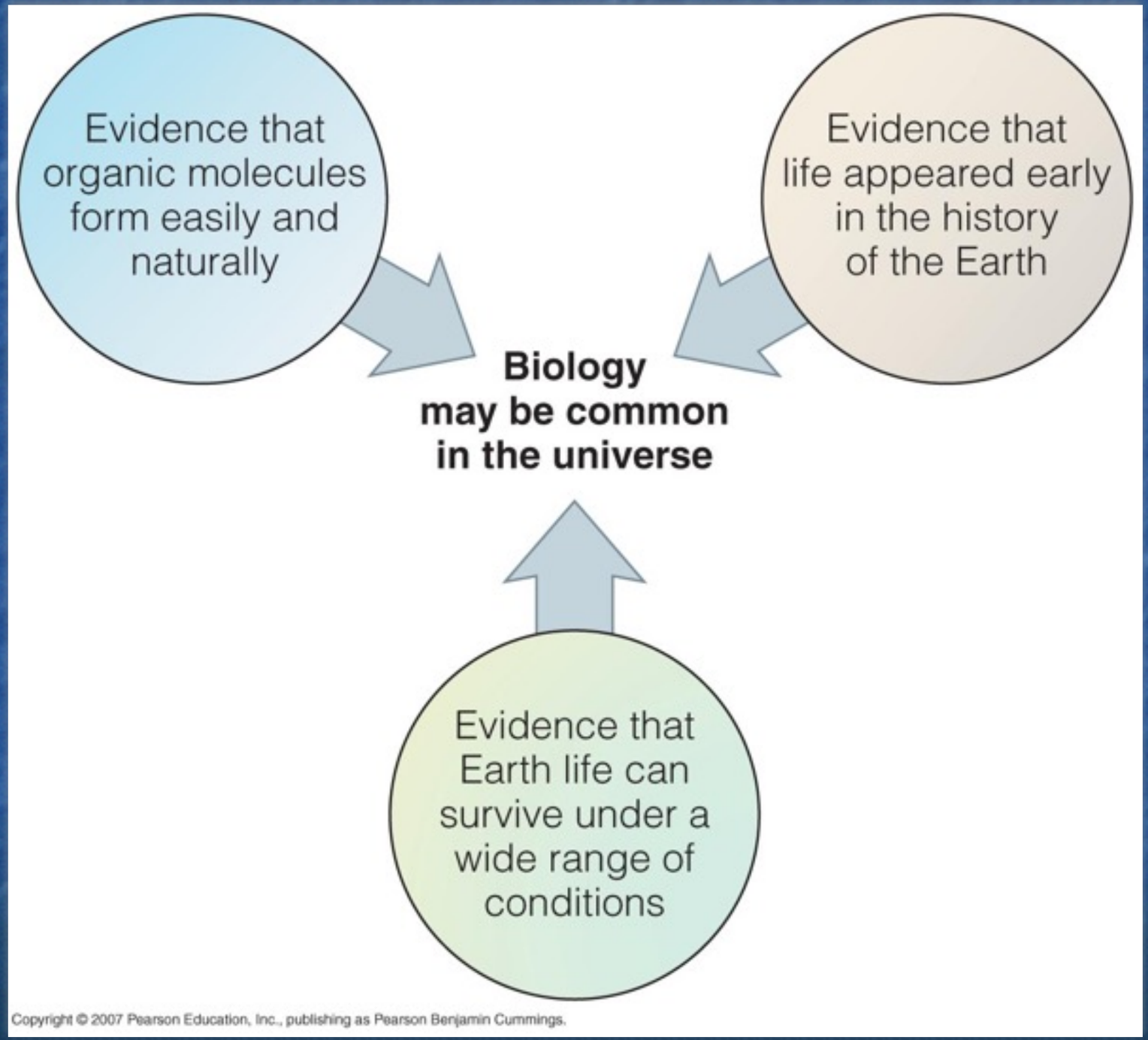
Possible scenarios?

- Fossilized evidence of life found on Mars
- Fossilized evidence of life found in a meteorite
- Evidence of photosynthesis in atmosphere of an extra-solar planet
- Signal from alien civilization (SETI)
- Living organisms found on a meteorite, comet or asteroid
- Aliens visit us
- Alien artifacts found on nearby planet
- Living biosystem within the Solar System

Overview of topics in this course

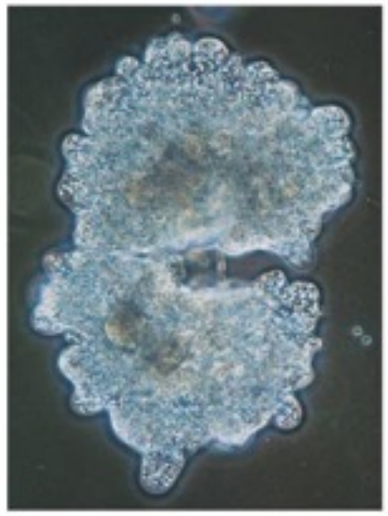
- Introduction to the Cosmos and the Solar System
- Life on Earth
  - What is life?
  - What makes Earth suitable for life?
  - How did life originate on Earth? How does it evolve?
- Life in the Solar System
  - Which locations in the solar system are "habitable"?
  - Searching for life on Mars, Europa, Enceladus, Titan, etc.
- Life beyond the Solar System
  - The discovery of planets around other stars
  - How common is the Earth?
  - The Search for Extraterrestrial Intelligence (SETI)

What does biology tell us about the possibilities of life in the Universe?



The key properties of life on Earth

a Order: Living organisms exhibit order in their internal structure, as is apparent in this microscopic view of spiral patterns in two single-celled organisms.

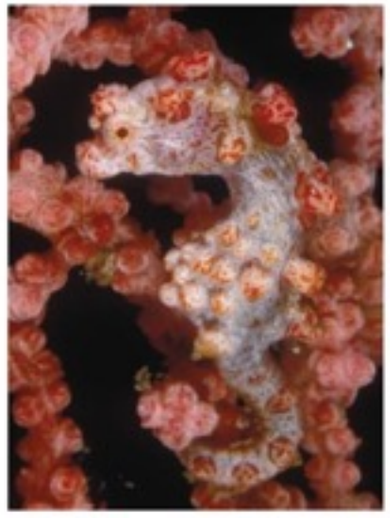


b Reproduction: Organisms reproduce their own kind. Here, a single-celled organism (an amoeba) has already copied its genetic material (DNA) and is now dividing into two cells.

c Growth and development: Living organisms grow and develop in patterns determined at least in part by heredity. Here, we see a Nile crocodile emerging from its shell.

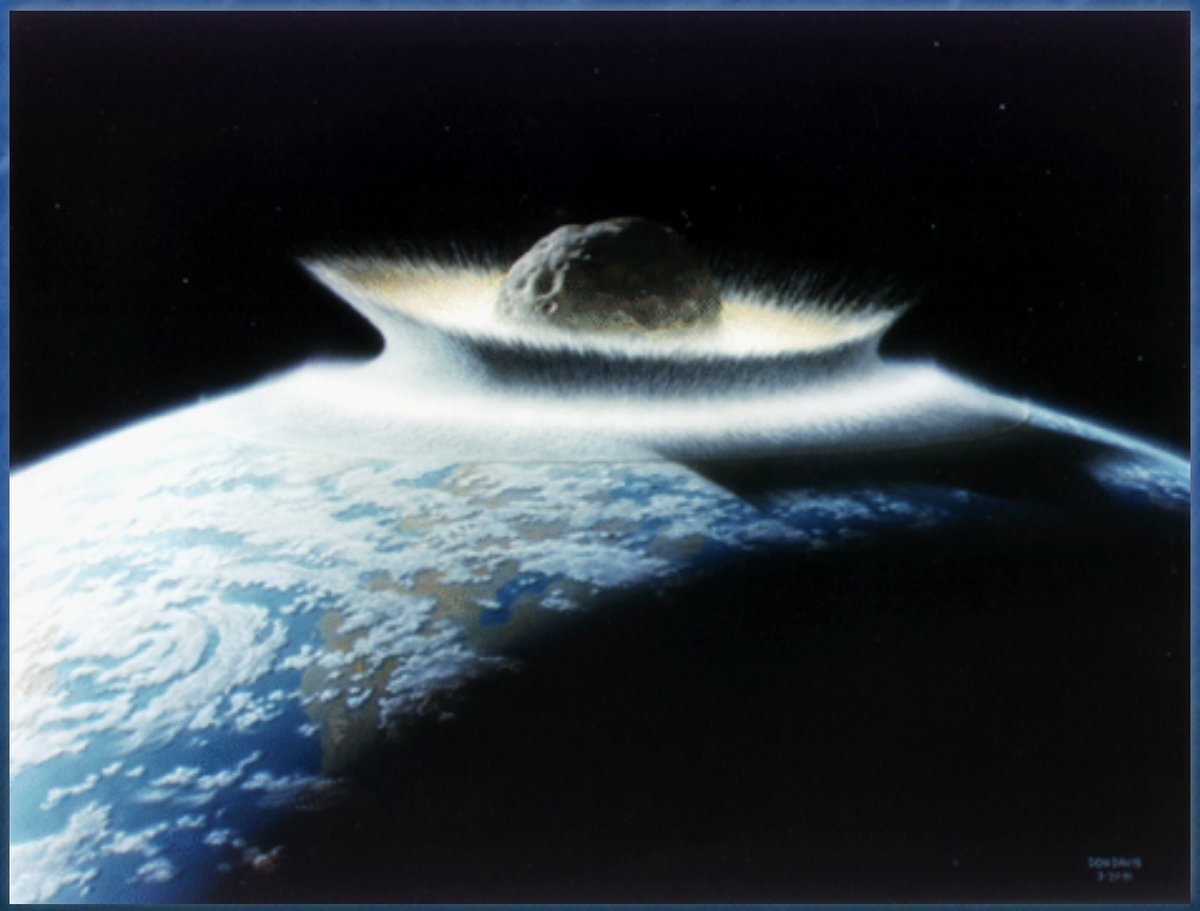
d Energy utilization: Living organisms use energy to fuel their many activities. These tube worms which live near a deep-sea volcanic vent, obtain energy from chemical reactions made possible in part by the heat released from the volcanic vent.

e Response to the enviornment: Life actively responds to changes in its surroundings. Here, we see a jackrabbit's ears flush with blood; the blood flow adjusts automatically to help the animal maintain a constant internal temperature by adjusting the heat loss from the ears.

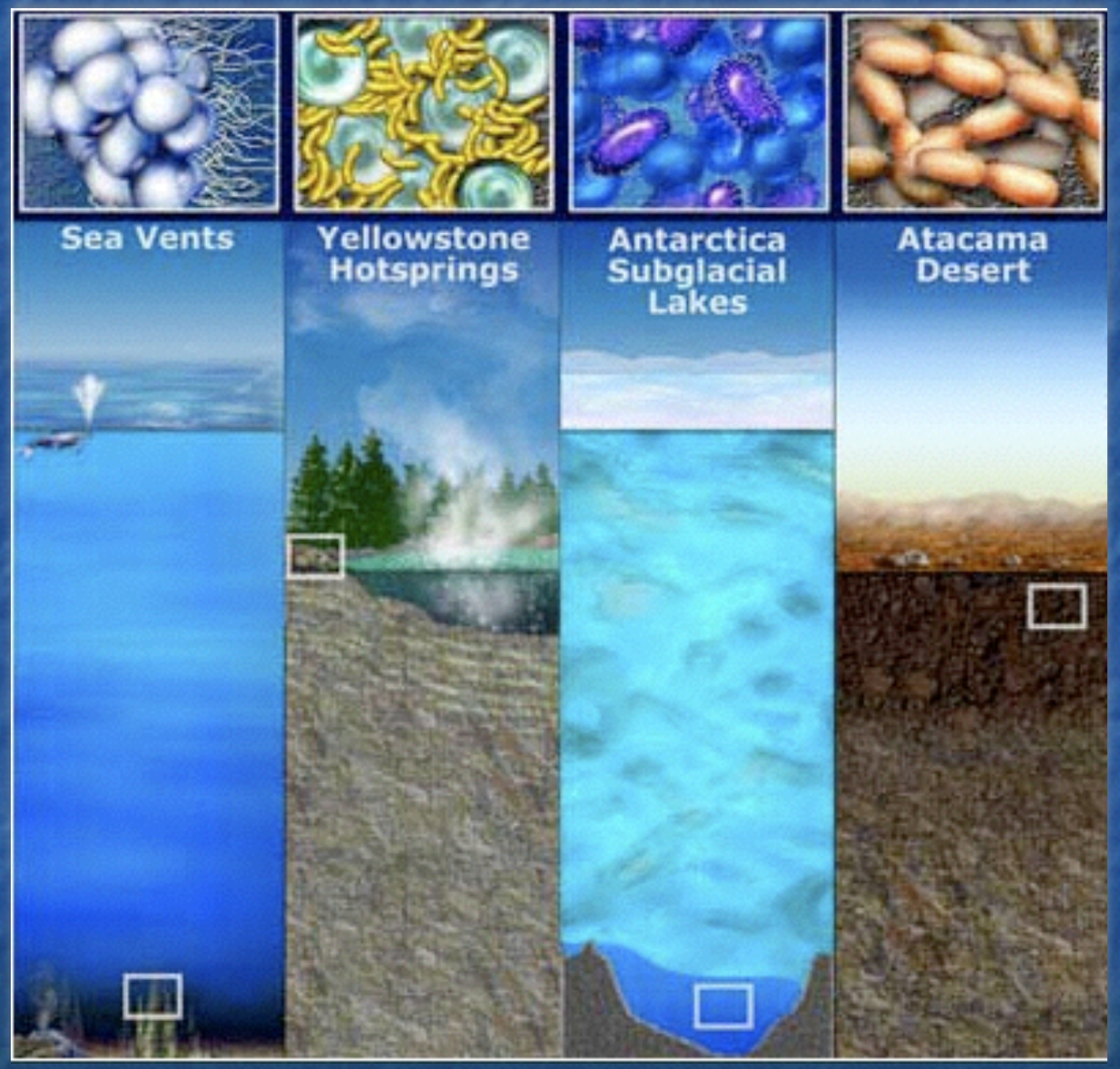


f Evolutionary adaptation: Life evolves in a way that leads to organisms that are adapted to their enviornments. Here, a pygmy seahorse is camouflaged in its coral surroundings.

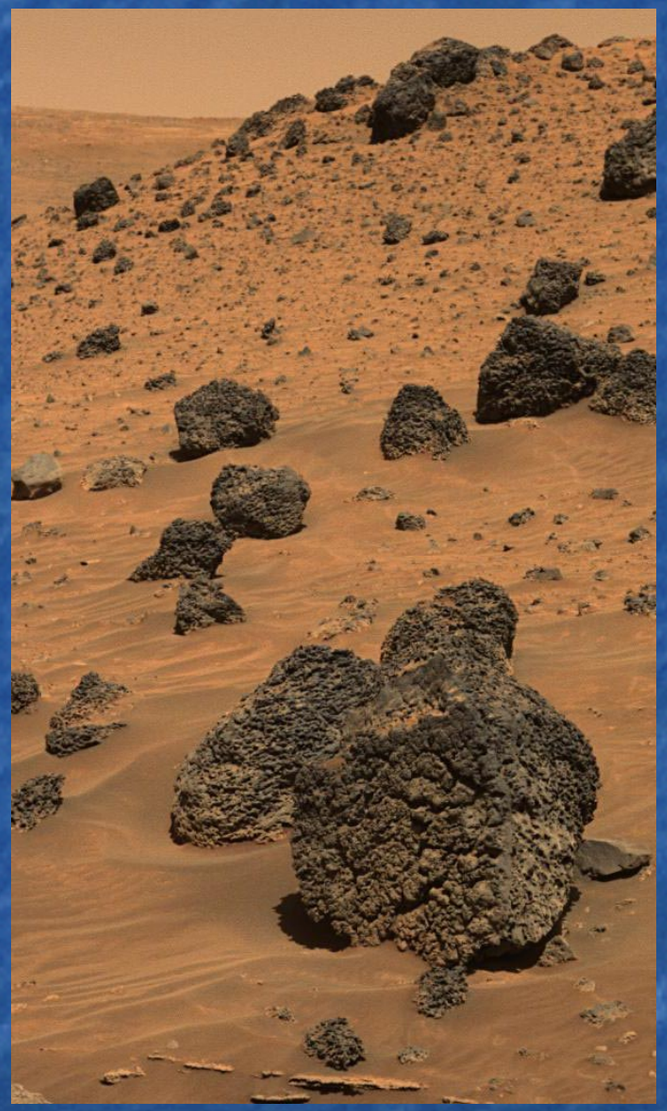
The evolution of Earth's habitability



Extremophiles on Earth

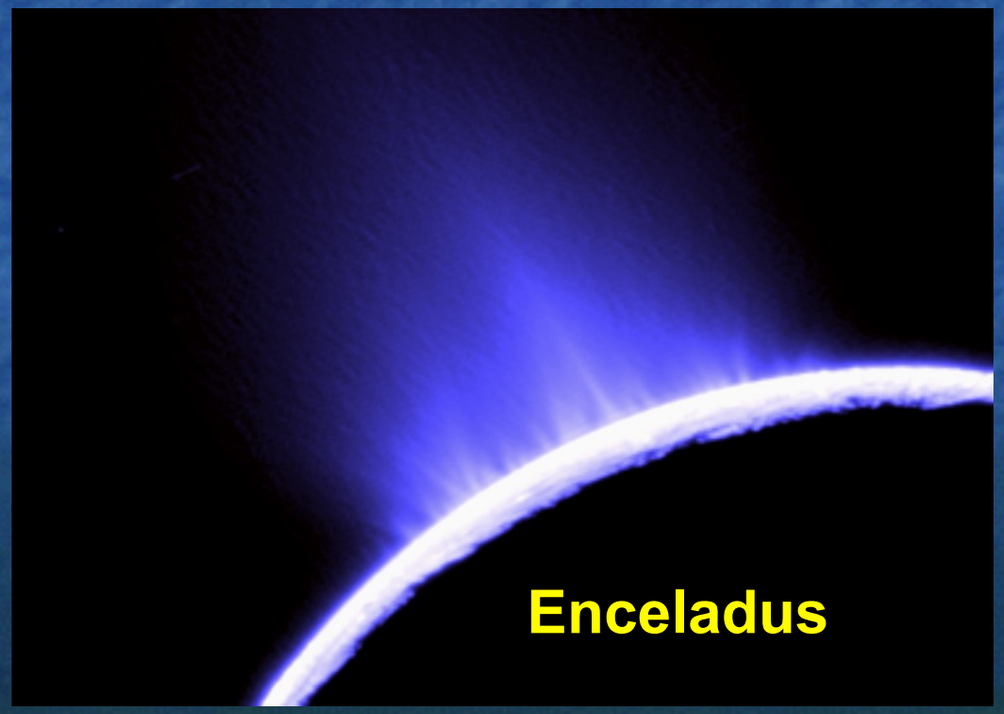


Places to look in the Solar System

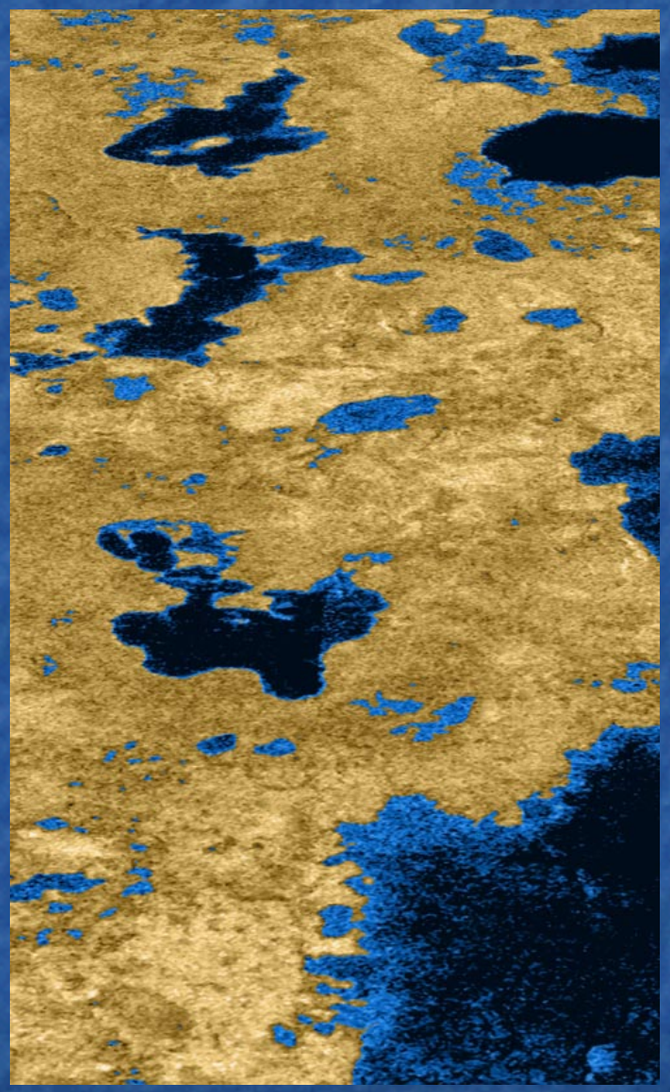


Mars

Europa

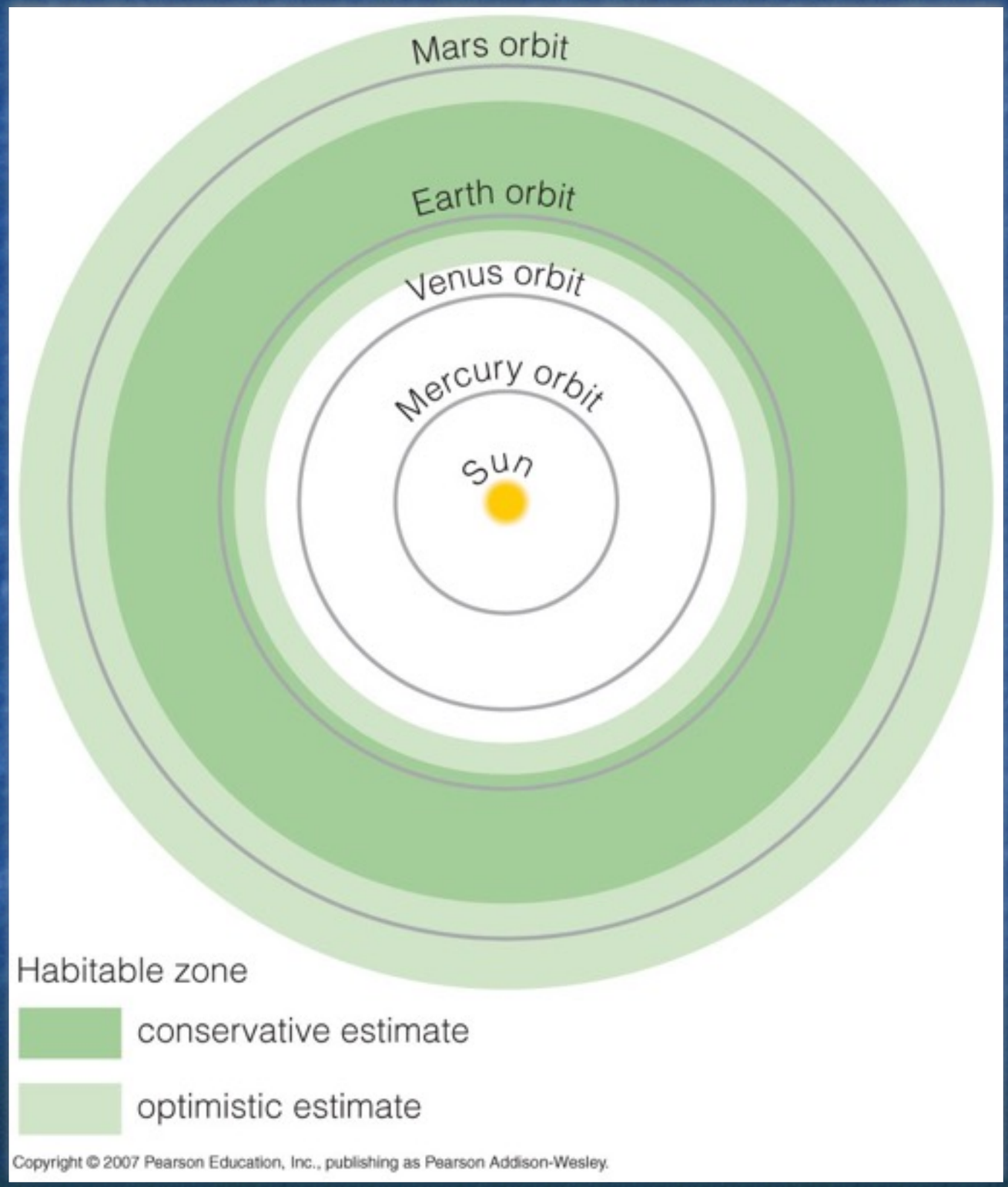


Enceladus

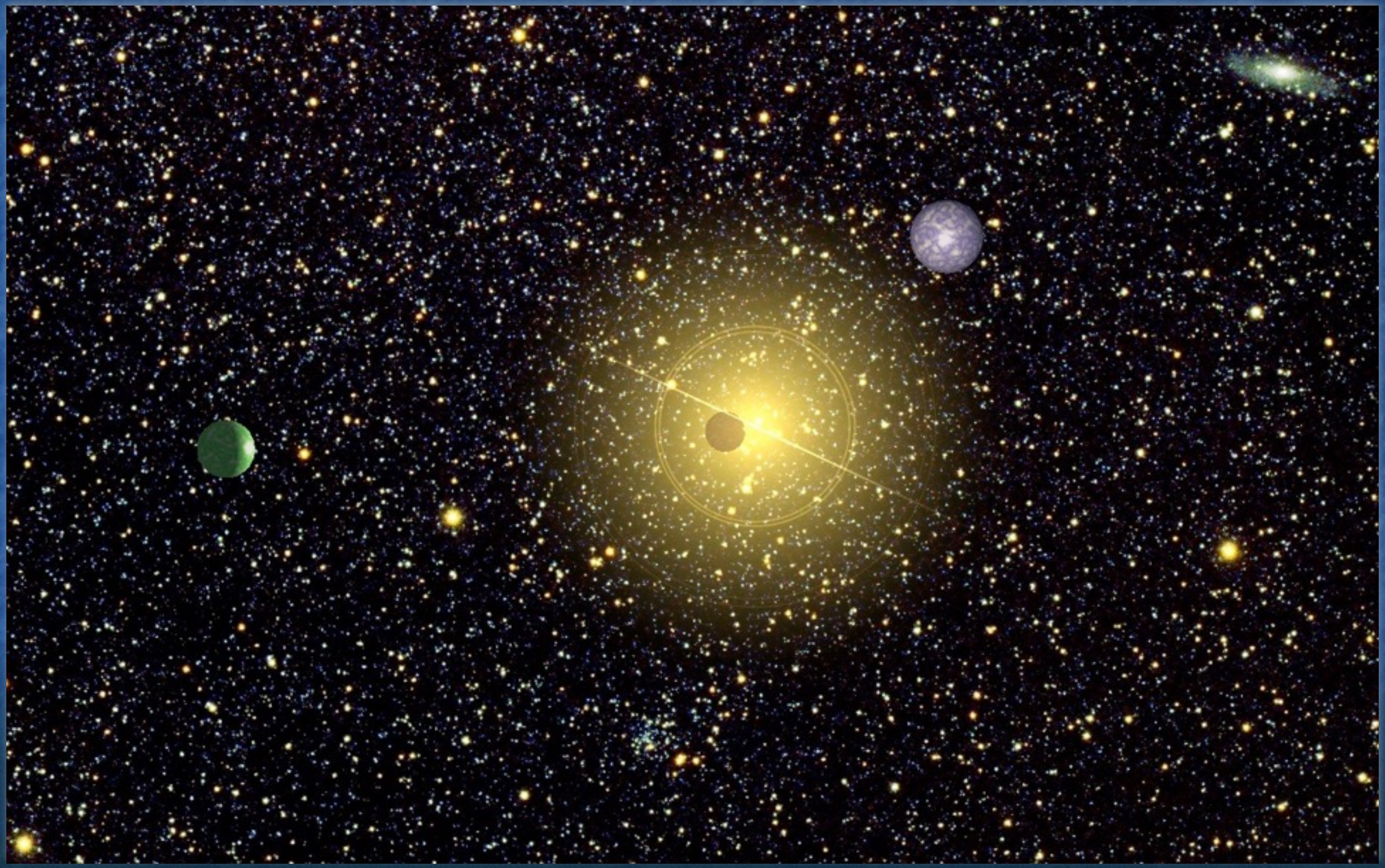


Titan

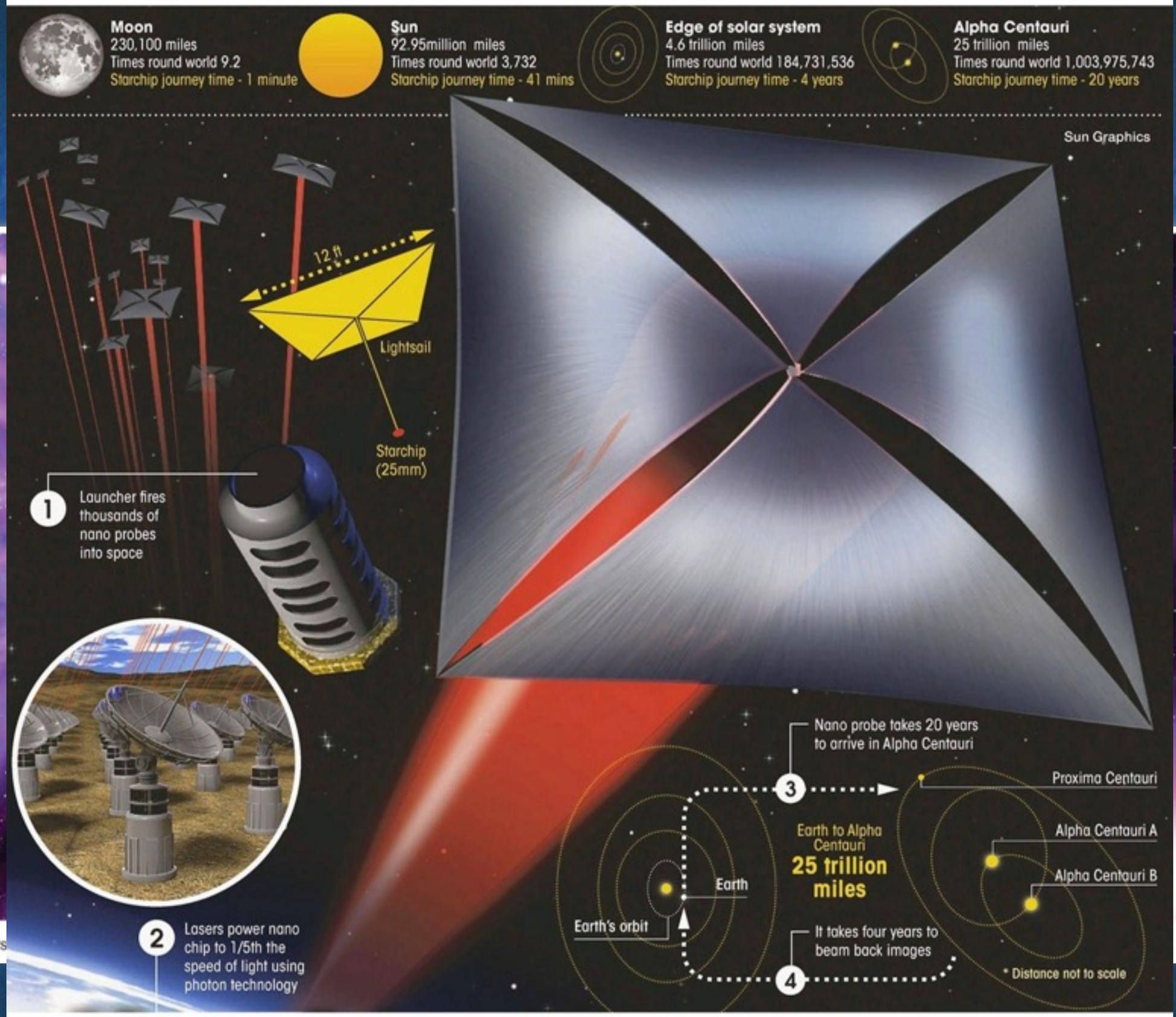
The Solar System's habitable zone



The nature of the known extra-solar planets



The search for extra-terrestrial intelligence (SETI)



Factors to consider

- How common is life?
  - if it is very rare, we're unlikely to find it elsewhere in our solar system, or even on nearby extra-solar planets
- How common are habitable planets? What can we learn from the Solar System?
- How difficult is interstellar travel?
  - for us or aliens!
- How do improvements in technology enhance our chances of finding life?
  - more sophisticated spacecraft
  - better telescopes
  - more thorough SETI searches

Before Next Class

- Read Chapter 3 from the textbook.
- Familiarise yourself with course website.
- Assignment 1 will be posted next week.
- Mid-term will be in-class Wednesday 23rd October.
- Details to follow.
- Lecture materials are posted online.
- Labs start on September 10th - be ready!