

Welcome to the 2024 YUPRA REU!

Mentors:
Rory Barnes & Jessica Birk



Overview

Over the next 10 weeks, you will learn

- Stellar astrophysics
- Bayesian statistics
- Machine learning
- How to present scientific results

Key Dates:

- June 18: Register for 1 credit independent study with Zach Shierl
- Aug 13: YVC Student Research Symposium
- Aug 17: Washington Space Grant Symposium in Seattle

Key expectations:

- Meet on campus 3 times / week
- Work ~40 hours / week total
- Be collaborative / supportive of each other!

Overview

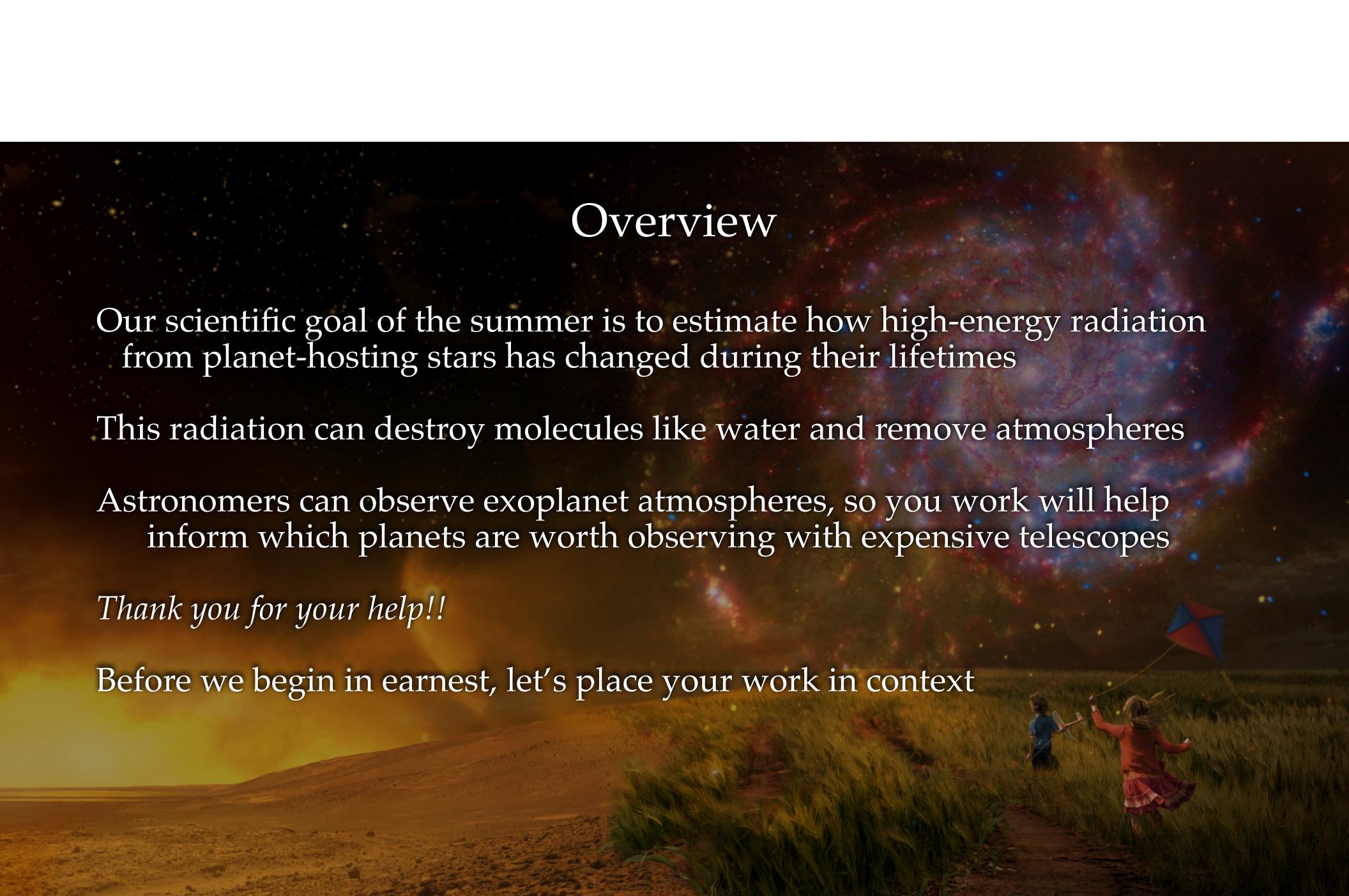
Our scientific goal of the summer is to estimate how high-energy radiation from planet-hosting stars has changed during their lifetimes

This radiation can destroy molecules like water and remove atmospheres

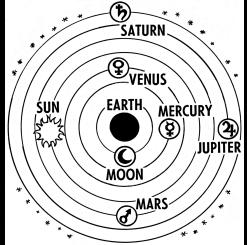
Astronomers can observe exoplanet atmospheres, so your work will help inform which planets are worth observing with expensive telescopes

Thank you for your help!!

Before we begin in earnest, let's place your work in context

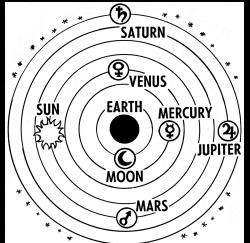


Science has illuminated humanity's place in the Universe

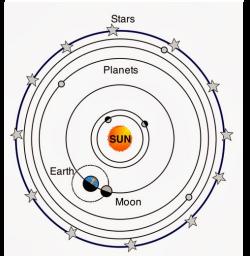


Geocentrism: Earth is the center of the universe; Sun and planets orbit Earth on perfect circles; stars fixed to a celestial sphere; promoted by Aristotle and Ptolemy
(Shown to be false in 1851 by Foucault's Pendulum)

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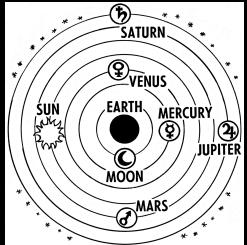


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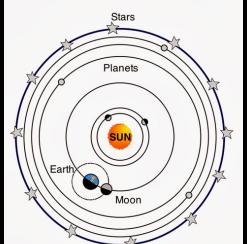


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(Johannes Kepler showed orbits are *elliptical* in 1609)

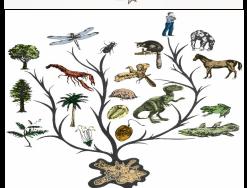
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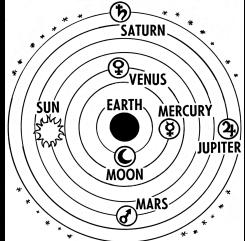


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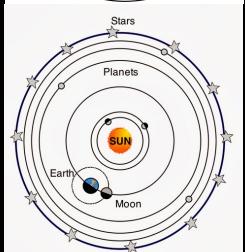


Evolution: All life related; some species go extinct; implies a *universal common ancestor*; proposed by Charles Darwin in 1859

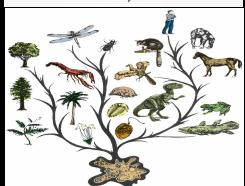
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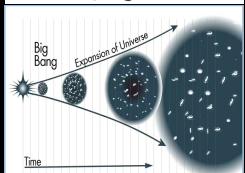
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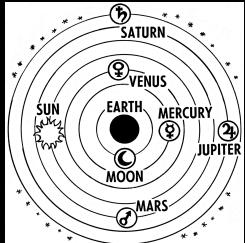


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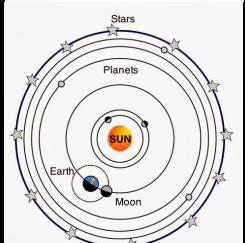


Cosmological: Universe is expanding; billions of galaxies hosting billions of stars; implies a starting time, the *big bang*; promoted by Edwin Hubble, Albert Einstein in early 1900s

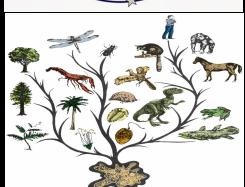
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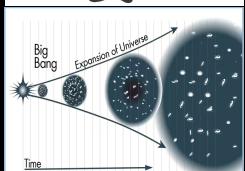
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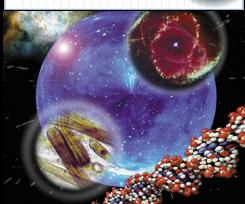
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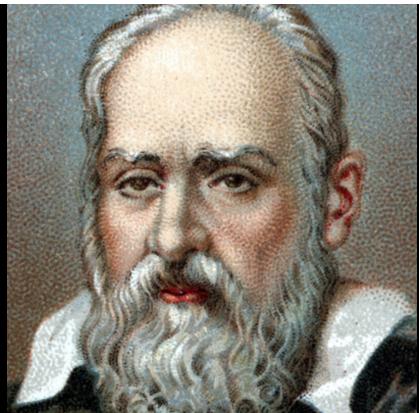
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Astrobiological? Earth is not the only planet that hosts life? 21st century?



Galilei Galileo

University of Padua, Italy

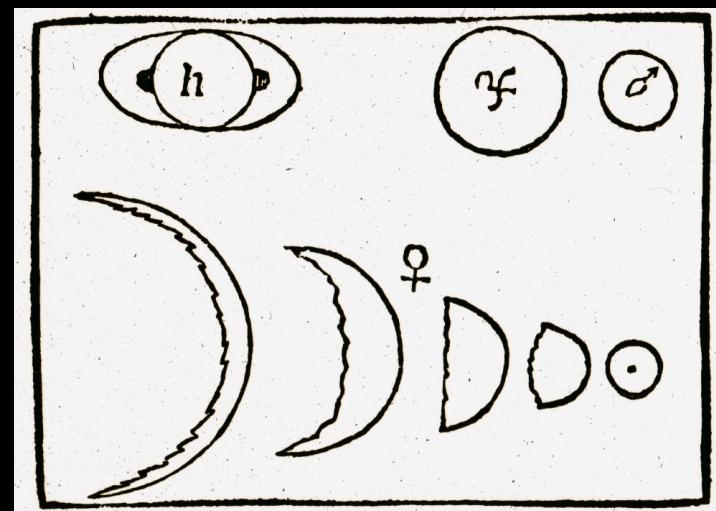
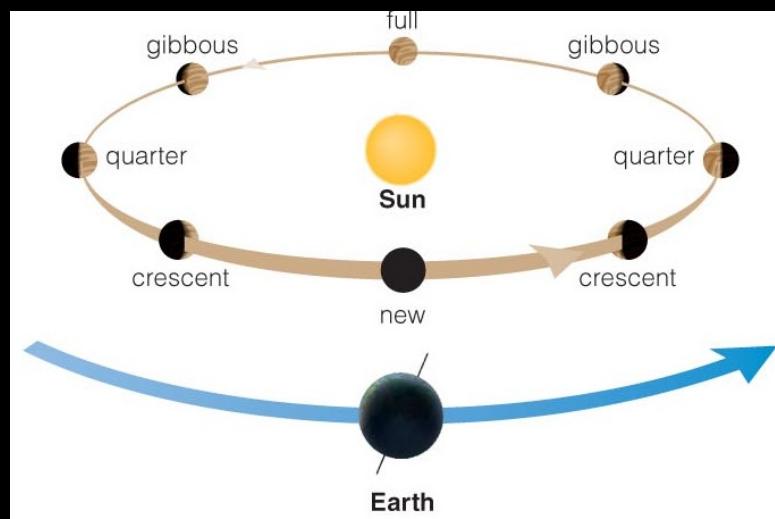
Used primitive telescope in 1609 to see the Moon's surface and
moons of Jupiter (telescope invented in 1608)

Reported in *The Starry Messenger* (1610)

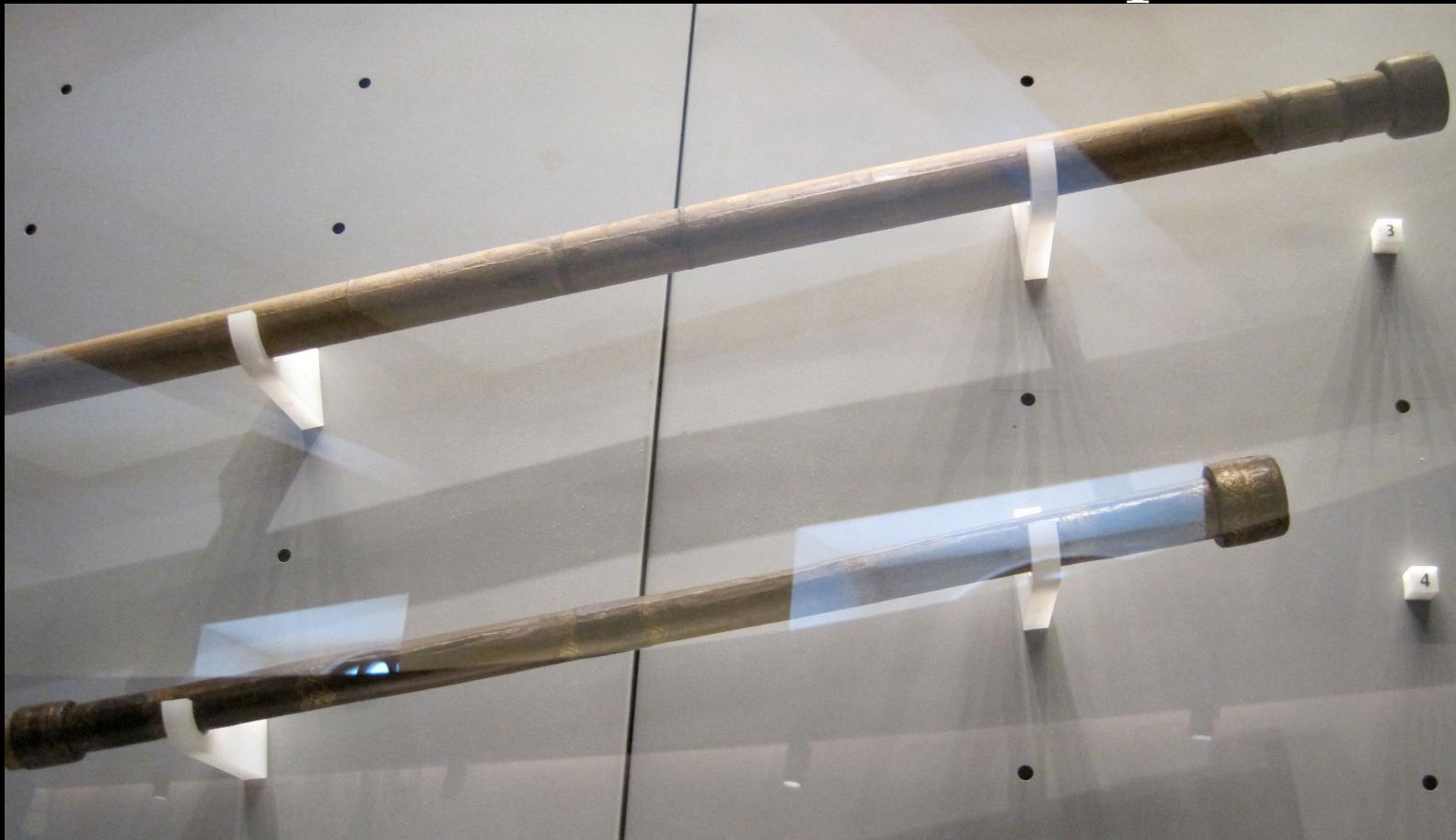
Caused fame throughout Europe

Then more discoveries:

- Venus has phases
- Saturn has ears! (the rings)
- the Milky Way consists of innumerable stars

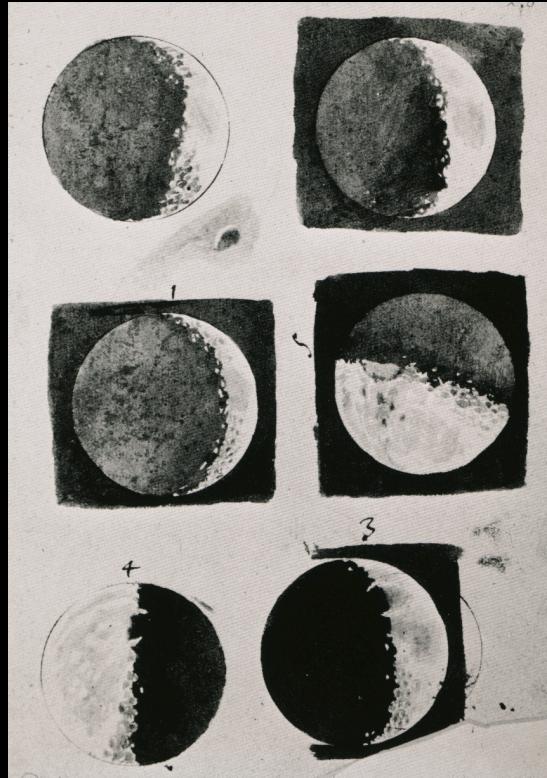


Galileo's actual telescopes



Galileo Discoveries (1609-10)

Heavenly bodies are
not perfect (Moon)!

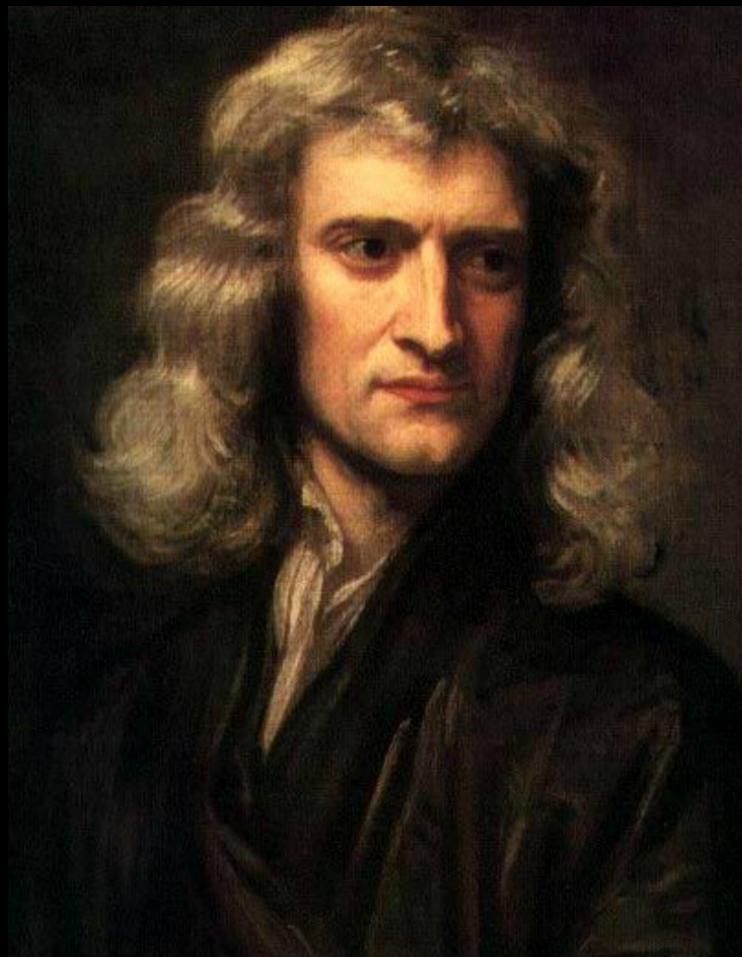


Objects go around another planet (Jupiter)

| Observations Performed | |
|-----------------------------|--|
| 2. J. 1609. March 12. | ○ ** |
| 3. mon ^d | ** ○ * |
| 2. Jun ^d | ○ *** * |
| 3. mon ^d | ○ * * |
| 3. Apr. 5. | * ○ * |
| 4. mon ^d | * ○ ** |
| 6. mon ^d | ** ○ * |
| 8. March 13. | * * * ○ |
| 10. mon ^d | * * * ○ * |
| 11. | * * ○ * |
| 12. H. 4 Aug ^d | * ○ * |
| 13. mon ^d | * * ○ * |
| 14. June. | * * * ○ * .. |
| 15. | * * ○ |
| 16. Clamit ^e | * ○ *** * |
| 17. Clamit ^e | * ○ * * |
| 18. | * ○ * * * |
| 21. mon ^d | * * ○ * * |
| 24. | * * ○ * |
| 25. | * * ○ * |
| 29. Aug ^d | ** ○ |
| 30. mon ^d | *** ○ * - |
| January 4. mon ^d | |
| 4. Aug ^d | * * ○ * |
| 5. | * * ○ * |
| 6. | * ○ *** |
| 7. | * ○ * * * media omnibus non apparentia rebus circa. |
| 7. Aug ^d | * ○ *** |
| 11. | * * * ○ |

Sentenced to house arrest in 1633 for heresy
Fared better than Giordano Bruno; burned at the stake in 1600

Isaac Newton



Principia (1687) - one of the most important books ever

Connected motion to mathematics (physics)

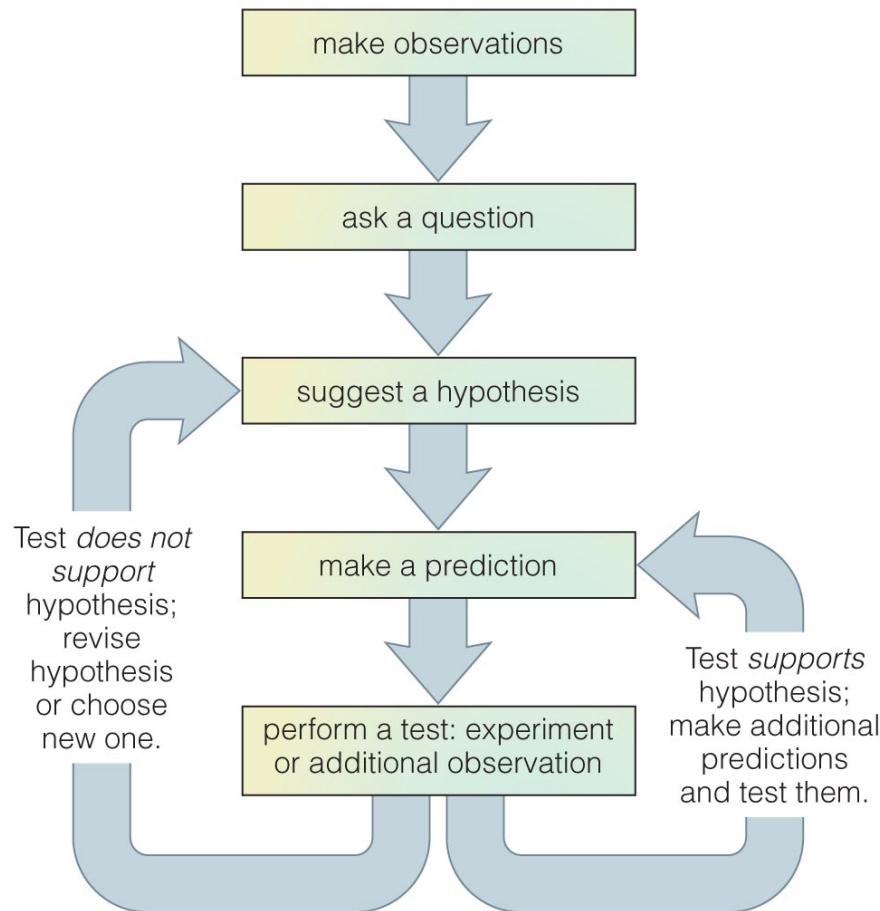
Kepler described motion of planets
-Newton described all bodies

Physics is universal and predictive
-can imagine surfaces other world

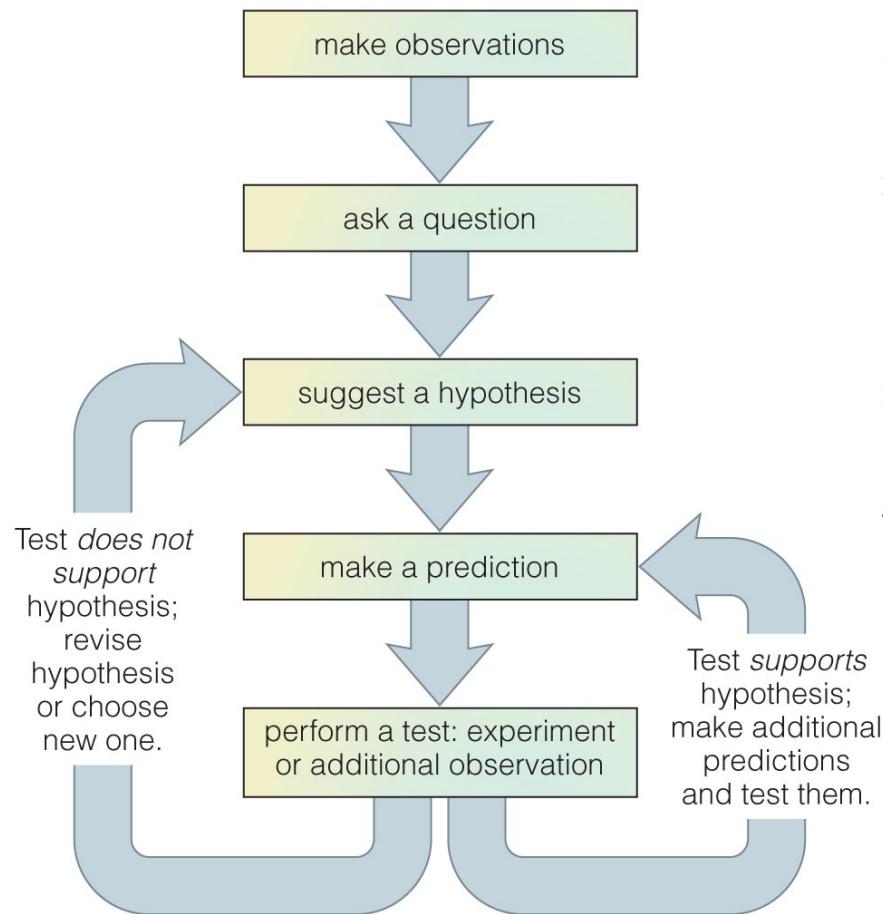
His gravitational law produced elliptical orbits for planets around the Sun

Basic elements of the scientific method

The Scientific Method



The Scientific Method



Science:

The systematic study of the structure and behavior of the physical and natural world through observation.

Scientific method:

Systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses

Science provides **objective knowledge** about our universe

Scientific Method in Reality...

- Serendipitous discoveries
 - Microwave background from the Big Bang (Arno Penzias and Robert Wilson, 1964)
 - Microwave cooking also! (Percy Spencer, 1946)
 - First antibiotic, penicillin (Alexander Fleming, 1928)
- Discovery / Adventure (“fishing expeditions”)
 - May not be hypothesis-driven
 - Send a probe to Mars and make measurements
 - Send a 22-yr-old on a voyage around the world (Charles Darwin, 1831-36)

Nature of Scientific Knowledge

Scientific knowledge is *falsifiable*

(science philosopher Karl Popper (1902-1974))

- If *tests* of theories (*attempts to falsify through observation*) fail, then the theory does not have corroborating evidence, i.e., theories live and die by the sword of data.
- A theory that cannot be tested by any conceivable means is not a scientific theory, it's *pseudo-science*
- Good theories make predictions, especially unexpected ones. Good theories forbid certain things from happening.
- A **scientific theory** is a model (conceptual representation) that explains a variety of observations through a few general principles. It attains the status of a theory by surviving tests.

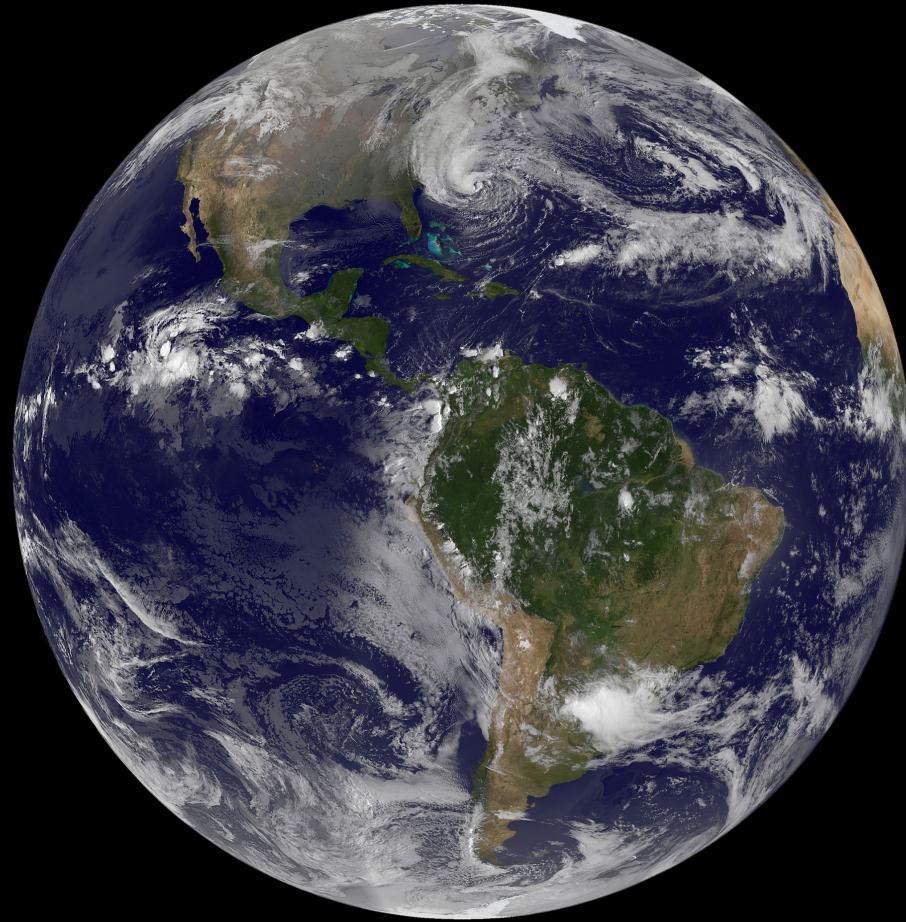
“What is *astrobiology*? ”

- NASA: “the study of the origins, distribution, evolution and future of life in the universe”.
- Or: “the study of the life in a cosmic context”
- Or: “the study of the origin and evolution of life on Earth and the possible variety of life elsewhere”
- Astrobiology seeks to answer unsolved questions:
 - How does life begin and develop?
 - Does life exist elsewhere?
 - What is life’s history and future on Earth and beyond?
 - It’s not just about “searching for life,”
 - It includes understanding and recognizing where life might be: “habitability”

“What is *astrobiology*? ”

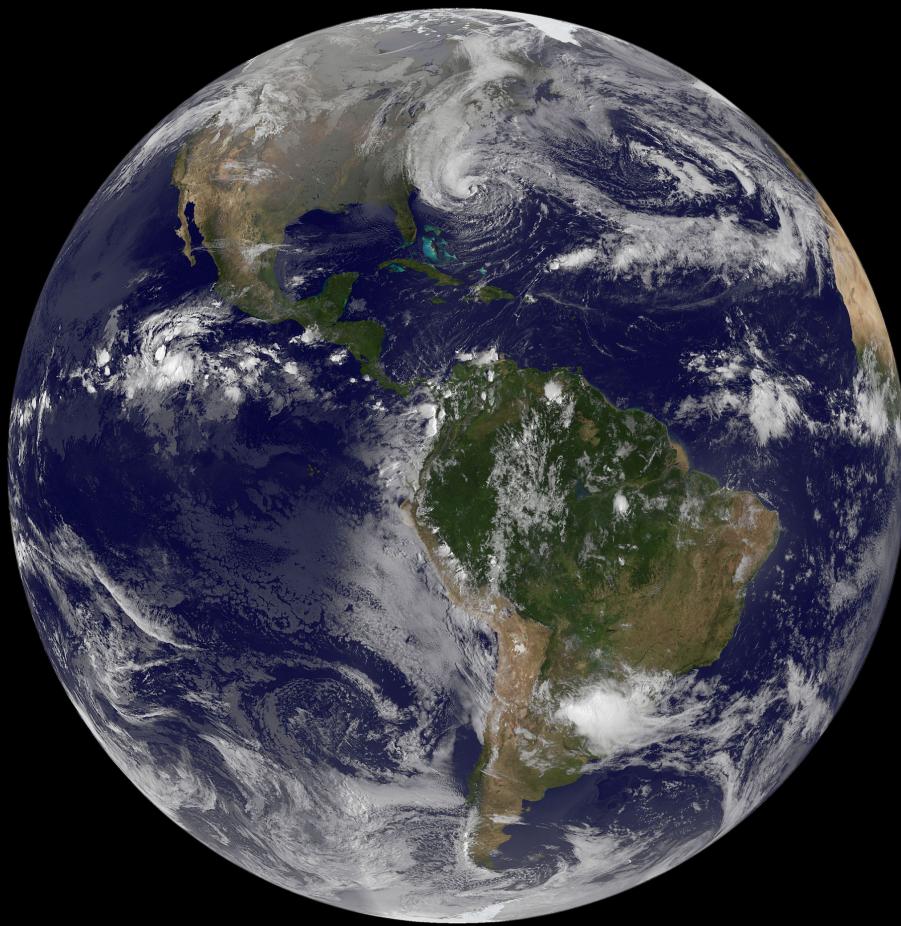
My definition: “Astrobiology is the study of how life originated on Earth, and how we can find life beyond Earth.”

Astrobiology is rooted a simple fact:



Earth is the only known inhabited world

How did we get here?



Are we alone?

These are *OLD* and *BIG* questions.

“There are infinite worlds both like and unlike this world of ours...
We must believe that in all worlds there are living creatures and
plants and other things we see in this world.”

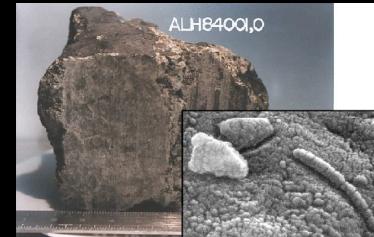
- Epicurus 300 BC

Why astrobiology *now*?

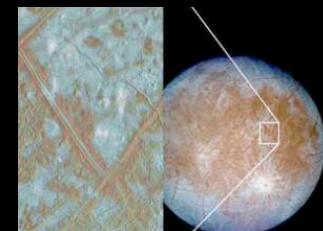
- 1) Biology frontiers: “extremophiles”
microbes thriving up to 121°C, or in ice,
very acid/alkaline conditions, very
salty water, high pressure...



- 2) Mars meteorite study in 1996
(considered flawed but still debated)



- 3) 1995-6: Europa (moon of Jupiter) likely
has a subsurface ocean



- 4) 1995: Discovery of “exoplanets”
around other stars



Astrobiology is “interdisciplinary”

- Astronomy
- Planetary science
- Biology
- Geology
- Atmospheric Science
- Anthropology
- Psychology

Modern science is compartmentalized. Disciplines are based on 20th century questions and data. 21st century questions require a realignment of scientific thought.

Astronomy and Astrobiology

- Replaced the “*geocentric*” model with the knowledge that we orbit an unremarkable star.
- Identified the source of life’s chemical elements.
- Universal laws of physics and chemistry.
- How planets form and what they are made of from observation and theory
- Discovery of exoplanets (planets around other stars). Over 4000 known and more than 4000 further candidates: A few smaller ones are thought to be “terrestrial” (meaning rocky); some may be habitable

The Cosmic Context : A Pale Blue Dot



Earth as a single pixel

Image by the Voyager 1 spacecraft (1990)

From the outer solar system (40 AU away)

[1 AU = 150 million km = 1.5×10^{11}

“...the delusion that we have some privileged position in the Universe..[is]... challenged by this point of pale light. Our planet is a lonely speck in the great enveloping cosmic dark”

- Carl Sagan

Planetary Science and Astrobiology

Planetary Science: The study of planetary atmospheres, surfaces and interiors, and planet formation and evolution.
Until recently, restricted to the Solar System.

We classify 2 basic types of planet:

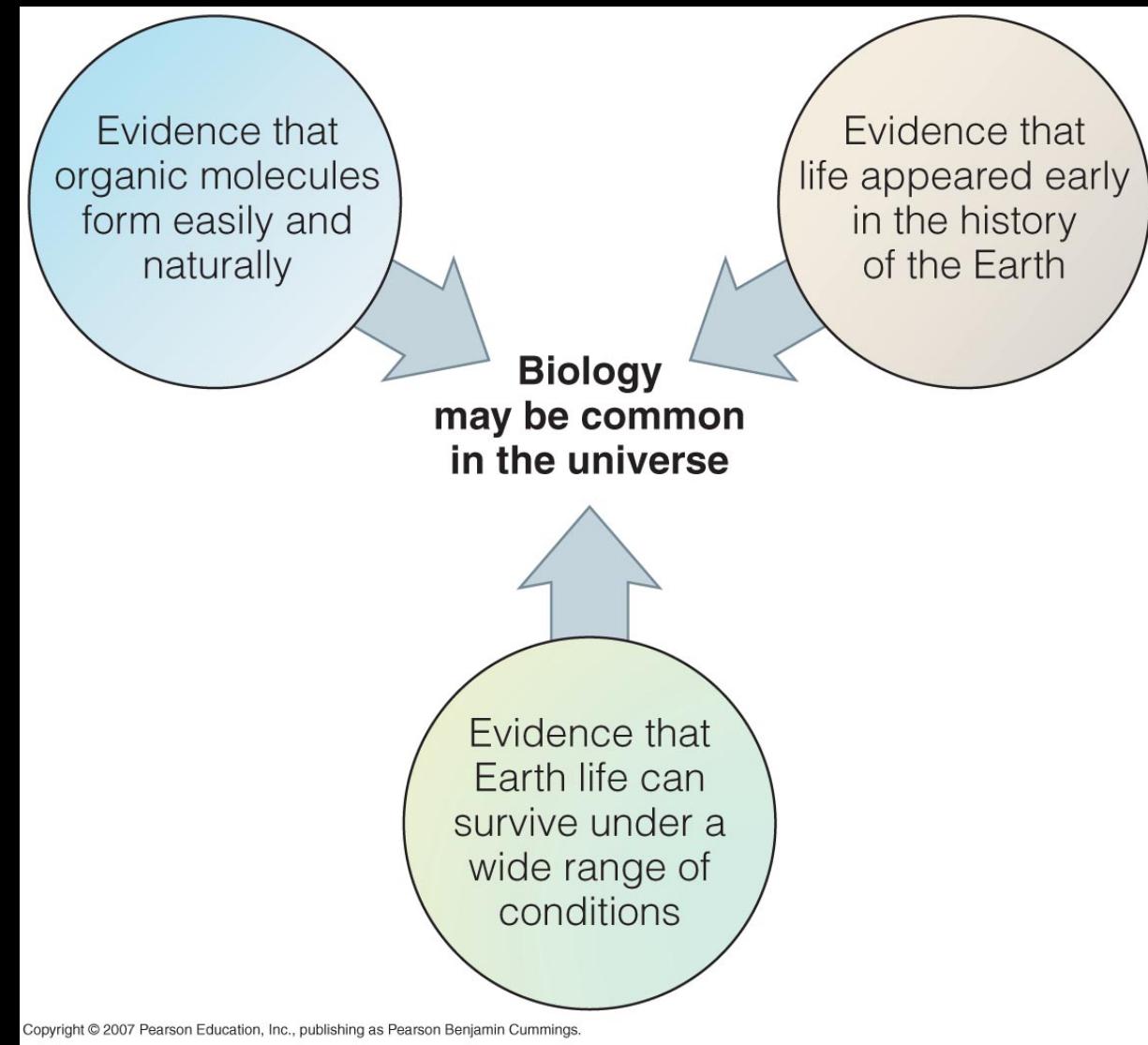
“terrestrial” meaning with a rocky surface

“giants”(made of gas or ice+gas)

Overall, planetary science guides our understanding of habitability

Biology and Astrobiology

- From geology: microbial life goes back more than 3.5 billion years on Earth
- Life evolved from a simpler common ancestor on Earth (a genetic family tree)
- Some microbial life can survive and prosper under a very wide range of conditions.
- All life requires 1) liquid water, 2) a handful of elements (the “bioessential” elements), and 3) energy



Each of You is Now a Professional Scientist

Science is the story of humans using their brains to illuminate the universe

You have inherited millions of lifetimes of work over millennia

It may feel intimidating, but every scientist started where you are today

“If I have seen further, it is because I stood on the shoulders of giants”

- Isaac Newton

I don't know if there's alien life in the universe, *and I don't care.*

- If yes, then we should learn about them to better understand ourselves
- If no, then we need to take *very good* care of our planet and its inhabitants

You are now part of the story of humanity learning its place in the universe!