

## ASTROBIOLOGY: SEEKING EVIDENCE OF LIFE BEYOND EARTH

## UC SANTA CRUZ

## WHAT IS ASTROBIOLOGY?

Astrobiology is the study of the origin, evolution, and prevalence of life in the universe.

Is life an inevitable consequence of cosmic evolution?

How does a planet become a living world with a global biosphere?

Are we alone in our corner of the Milky Way, or is life common?

These are the questions UC Santa Cruz astrobiologists are working to answer.

## Are we alone in the universe? UC Santa Cruz's Astrobiology Initiative seeks new answers to this ancient question.

By probing how life forms, identifying the markers life creates, and observing our local astronomical neighborhood, astrobiology brings a 21st-century approach to a timeless puzzle: What processes give rise to complexity and self-awareness in the universe?

"The search for evidence of life beyond Earth is neither pipe dream nor daydream but rather an open road to the end of our cosmic loneliness."

Natalie Batalha, UC Santa Cruz Professor of Astronomy and Astrophysics, former science lead of NASA's Kepler Mission

## We may soon know if we have interstellar neighbors.

NASA's recently completed Kepler Mission catalyzed a global scientific pivot toward the search for life beyond Earth, and UC Santa Cruz stands at the forefront of the field.

Built to find planets outside the solar system, or exoplanets, Kepler found that there are likely billions of planets in our galaxy with the basic conditions required to support life as we know it.

In the next decade, spacecraft will visit the watery worlds of our solar system able to detect complex organic molecules. The most powerful telescopes in history will look through the atmospheres of exoplanets for gasses created by living organisms. With faculty who are world leaders in the study of exoplanets, the origin of life, planetary science, and instrument development, UC Santa Cruz Astrobiology will continue its groundbreaking research while training diverse new generations of astrobiologists.

This new field calls for collaboration, and UC Santa Cruz has a tradition of crossing boundaries between research disciplines. The humanities, social sciences, and the arts will play central roles, engaging the public in our discoveries and their societal implications.

This may be the dawn of a scientific revolution, and you're invited to take part. UC Santa Cruz donors will be critical to what happens next, enabling scientists to commit to new collaborations and providing tools and resources to accelerate their work.

## IT'S ALREADY HAPPENING HERE

From the study of the forces that form stars and planets, to the search for exoplanets, to understanding what markers of life we can see across the galaxy, UC Santa Cruz researchers are already at work building the astrobiology field:

- tracing the history of life on Earth
- pushing ever closer to understanding how life's building blocks form
- documenting the processes that shape planets in the solar system
- filling in the whole picture of planets beyond the solar system
- building the instruments the world uses to explore the cosmos



## Origin of life

A team led by David Deamer has synthesized RNA-like molecules by reproducing the conditions in which life might form in hot springs. This challenges the consensus that life on Earth originated near deep sea volcanic vents—and could be a step toward identifying the type of planetary surface astrobiologists will look for.

## WE BUILD THE TOOLS

We build the technology that will make this search possible. UC Santa Cruz is home to the world-class instrumentation facilities of UCO/Lick Observatories and its Center for Adaptive Optics. Our inventions help observatories around the globe see farther and clearer. We have a long record of overcoming the challenges involved with making observations of objects light years away.



## PIONEERS IN ASTROBIOLOGY

## **Professor Natalie Batalha**

A global leader in astrobiology, Batalha oversaw the scientific work of the Kepler Mission. Under her direction Kepler exponentially expanded the number of known exoplanets and the estimate of potentially habitable planets—sparking the worldwide acceleration of astrobiology.

Batalha led the analysis that yielded the discovery in 2011 of Kepler 10b, the first confirmed rocky planet outside our solar system. In 2017, *Time* magazine named her one of the 100 most influential people on Earth.

Batalha, who earned her Ph.D. in astrophysics at UC Santa Cruz, left NASA to establish and direct the UC Santa Cruz Astrobiology Initiative.

## **Professor Ruth Murray-Clay**

The inaugural holder of the Gunderson Chair in Theoretical Astrophysics, Murray-Clay's influential investigations of planetary systems and atmospheres have earned widespread recognition, including the American Astronomical Society's Helen B. Warner Prize for Astronomy.

## **Professor Jonathan Fortney**

An expert on the atmospheres and interiors of giant planets, Fortney directs the UC Santa Cruz–based international exoplanet collaboration, the Other Worlds Laboratory. He has helped NASA interpret spacecraft observations of Saturn and Jupiter as well as Kepler's exoplanet data.

#### **Professor Zac Zimmer**

An accomplished analyst of the interplay between scientific discovery, science fiction, and world history, Zimmer's current focus is on literary representations of the 16th-century conquest of the Americas–Earth's most relevant historical experience of an initial encounter.

Emeritus Physical and Biological Sciences Dean Frank Drake created the Drake Equation to represent of the challenges in predicting how hard it would be to detect extraterrestrial civilizations—five decades later, it continues to inspire the search for life.

**The Drake equation** Kepler produced strong evidence regarding the percentage of stars with planets, f(p), and the portion that might be habitable, n(e).



Number of technologically advanced civilizations in the Milky Way galaxy



Rate of formation of **stars** in the galaxy



Fraction

of those

stars with

planetary

Number of planets, per solar system, with an environment suitable for life



Fraction of suitable planets on which life actually appears



Fraction of life-bearing planets on which **intelligent life** emerges



Fraction of civilizations that develop a technology that releases detectable signs of their existence into space

Length of time such civilizations release detectable signals into space



## UC SANTA CRUZ ASTROBIOLOGY

The James Webb Space Telescope is scheduled to launch in 2021, starting a new era in the study of exoplanet atmospheres. On Earth, a new generation of 30-meter reflector telescopes with the potential to find evidence of life on planets orbiting some of the closest stars will begin operating in the next decade. Engineers are hard at work planning the space missions beyond Webb, equipped to detect the chemical signatures of life beyond the solar system.

Closer to home, robotic spacecraft will further explore Mars as well as Jupiter's moon Europa and Saturn's moons Titan and Enceladus, seeking signs of life.

With influential achievements in exoplanet science, life sciences, and planetary science, UC Santa Cruz researchers have made many of the discoveries that established this field. As new tools expand the possibilities of inquiry, UC Santa Cruz Astrobiology is ensured continued leadership.

## Training the next generation of astrobiologists

The search for life is multigenerational. The students we train today will be the pioneers of tomorrow. UC Santa Cruz will tune and focus its outstanding, cutting-edge curriculum and create new courses, building an

interdisciplinary degree program in astrobiology. Graduate student fellowships will create opportunities for thesis research co-mentored by faculty in multiple departments.

## **Sharing discoveries**

Public lectures and engaging events will provide opportunities for audiences to connect with researchers and their findings and to share in the achievements and progress of the field.

## **Diversifying the sciences**

Diverse perspectives lead to greater innovation. UC Santa Cruz established the nation's first endowed faculty position dedicated to making astronomy more inclusive. Astrobiology is committed to achieving this vision through greater accessibility, community building, diverse mentorship, and inclusive practices.

## **Connecting lessons to sustainability on Earth**

Astrobiology will teach us the limits of planetary habitability, informing us about our own biosphere and Earth's fragility and uniqueness. Our closest planetary neighbors appear lifeless. In its low-pressure, low-surface-gravity environment, Mars has been unable to hold onto surface liquid water while our sister planet, Venus, is hot enough to melt lead on its surface. As we work to understand the limits of planetary habitability, we will learn about the sustainability of life here on planet Earth.

## The ethics of exploration

What does humanity's history with "colonization" teach us about our future in space exploration? How can we be good planetary stewards for Earth, as well as other planets we might visit? The UC Santa Cruz Center for Public Philosophy excels at unpacking and sparking discussion on humankind's most difficult questions.



#### **Reporting the work**

The UC Santa Cruz Science Communication program is world renowned for training top science journalists. Alumni include reporters and editors for NPR, *National Geographic*, Ars Technica, and *Scientific American*. UC Santa Cruz Astrobiology's first fellow will be a Science Communication student who will further this program and communicate astrobiology findings to the public.

## Science and art

At the nexus of science and art is wonder. Understanding the meaning of the science and conveying it to a general audience will demand creative forms of expression. Artists in residence will work closely with scientists to share the significance of their findings effectively and accurately.

## **Truly interdisciplinary**

Astrobiology at UC Santa Cruz brings together scientists, scholars, and artists. As we grow humanity's knowledge, we will spark conversations through which society evolves.



#### Life in our solar system?

In the next decade new robotic missions will launch toward Mars, Jupiter's moon Europa, and Saturn's moon Titan. All will be equipped to seek clues about the formation of life. Each of these destinations could have unique niches where life exists or once existed.

Whether or not these missions gather the first evidence of extraterrestrial life, they promise to significantly extend our understanding of the environments of these distant worlds.

## NOW IS THE TIME

In 2017, responding to discoveries made during Professor Natalie Batalha's leadership of the Kepler Mission, Congress made the search for life beyond Earth a NASA objective. Across the country, scientists are accelerating the pace of astrobiology.

Faculty have begun strategic planning, implementing pilot programs, laying the groundwork for new courses and research endeavors, and designing compelling public events. Our work will represent the contributions of increasingly diverse researchers and ensure humanity truly understands the knowledge that is coming.

UC Santa Cruz Astrobiology launches in 2020.

UC Santa Cruz is poised to spearhead this scientific revolution, and we hope you will join us on the journey.



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WE INVITE YOU TO JOIN US ON THIS GREAT FRONTIER OF SCIENCE AND HUMANITY.

