Life on Ancient Earth and Alien Planets: UAizona to Lead NASA Astrobiology Projects

The NASA Astrobiology Program has selected eight new interdisciplinary research teams to inaugurate its Interdisciplinary Consortia for Astrobiology Research program,
including two teams at the University of Arizona. Led by Betül Kaçar [4] and Dániel Apai [5], the teams were selected from a pool of more than 40 proposals. The breadth and depth of the research of these teams spans the spectrum of astrobiology research, from cosmic origins to planetary system formation, origins and evolution of life, and the search for life beyond Earth.

The two ICAR grants total approximately $12 million.

"Being part of this inaugural effort will position the University of Arizona in a leading role at the forefront of the most pressing and challenging questions in astrobiology," said University of Arizona President Robert C. Robbins. "It is an incredible honor to have two teams from the university selected for this important work and I look forward to following their progress in this groundbreaking research."

Astrobiology is a discipline devoted to the study of the origins, evolution and distribution of life in the universe, the declared goal of NASA's Astrobiology Program. The program is central to NASA's continued exploration of the solar system and beyond, and supports research into the origin and early evolution of life, the potential of life to adapt to different environments, and the implications for life elsewhere.

Kaçar's ICAR project team is named Metal Utilization and Selection Across Eons, or MUSE [6], and will explore "What Life Wants: Exploring the Natural Selection of Elements," which focuses on a question fundamental to the field of astrobiology as a whole, she said.

"What are the essential attributes of life, and how should they shape our notions of habitability and the search for life on other worlds?" Kaçar said. Motivated by this broad question, her project team will explore the natural selection of the chemical elements during the coevolution of life and environment on Earth.

"We will connect earth sciences with astronomy and biology, using tools drawn from synthetic biology, genomics and evolution, as well as geochemistry and biochemistry, to pioneer an entirely new scientific discipline – 'evolutionary metallomics' – studying the evolution of metal use in biological pathways, particularly the biological nitrogen cycle."

Kaçar's research program will cultivate a new cohort of scientists with experimental and analytical expertise who can combine earth and life science disciplines to inform astrobiology search strategies. Being able to tease apart the essential attributes of life would have a direct impact on scientists' ideas of habitability and the search for life on other worlds.

"While we have learned a tremendous amount about how nature uses these elements in the biochemistry of organisms, there remains deep uncertainty about why evolution selected for these elements," she said. "In other words, what does life want, and why does it want what it wants?"
Kaçar’s team will approach this puzzle by studying life on early Earth. This will involve geochemical and biological investigations that involve ancient materials, experiments and modern natural systems, such as tracking down microbes in extreme environments and remote locations, as well as studying ancient variants of proteins and microbial metabolisms in the lab.

"ICAR will allow us to rewind the evolutionary clock in the laboratory, and explore the evolution of reconstructed ancient proteins, and experimentally study their characteristics," Kaçar said. "We look forward to supporting NASA’s Science Mission Directorate on priority astrobiology goals."

The project will bring together earth scientists and life scientists in a unique, problem-focused collaboration closely aligned with NASA’s strategies, Kaçar said.

"It is easy to see on Earth today that life depends on certain elements," she said. "We want to study whether this dependence is an inevitable consequence of the elements available to life, or whether it is an accident of history that might have worked out very differently if we replayed the tape of evolution under slightly different conditions – as seems inevitable on other worlds."

Apai is an associate professor in the UArizona departments of astronomy and planetary sciences, and Kaçar is an assistant professor with joint appointments in the departments of molecular and cellular biology and astronomy and planetary sciences. She also is a member of UArizona’s BIO5 Institute.

The team led by Apai, "Alien Earths," is poised to transform scientists’ understanding of the habitability of nearby planetary systems. Alien Earths will carry out 14 closely coordinated research projects, including theoretical, laboratory analysis and observational studies.

Recent discoveries suggest that habitable planets may be very common, Apai said, which begs the question, "Which nearby planetary systems are likely to host habitable planets and possibly life?" NASA and the astrobiology community are working on ideas for powerful next-generation space telescopes that could scan the atmospheres of nearby planets for gases that indicate the presence of life.

"Earthlike planets remain very difficult to find and, even more so, to characterize," Apai said. "Our team will help assess which nearby planetary systems are more likely to be good targets, an essential step in defining the optimal strategy for our search for life in the universe."

Apai’s ICAR grant builds on and extends a major research program led by his group called "Earths in Other Solar Systems," or EOS, a five-year program that led to more than 140 refereed scientific papers and is now in its final year of funding. EOS is dedicated to finding out how habitable planets form, and the new ICAR project will take those insights, complement them with new projects, and apply the combined knowledge to nearby planets to investigate
which ones may be suitable for life, Apai said.

"Like EOS, Alien Earths will not only be a fascinating research program," Apai said. "We defined it strategically to closely tie into upcoming and next-generation NASA exoplanet missions, with the goal to inform, guide and enhance the capabilities of future NASA missions that search for life on other worlds."

The NASA ICAR award is critically important to launch the work of the Alien Earths team, a team of more than 50 undergraduate and graduate students, plus junior and senior researchers from seven countries. The team will form a powerful, international, multidisciplinary hub for the exploration of habitable planetary systems.

Both projects will include interdisciplinary collaborations within UArizona, connecting Steward Observatory and the Lunar and Planetary Laboratory [9], with the departments of molecular and cellular biology, chemistry and biochemistry, computer science, ecology and evolutionary biology, and the BIO5 Institute.

"The University of Arizona has deep, unparalleled expertise and decades-long tradition in space science, and, perhaps now more than ever, we are focused on leading ambitious, imaginative research programs that leverage our unique capabilities while bringing together talented scientists from across the state and nation," said Elizabeth "Betsy" Cantwell, senior vice president for research and innovation. "Drs. Kaçar and Apai's astrobiological research is absolutely demonstrative of that effort."

The Alien Earths team is led by the University of Arizona and includes the following partner institutions: Arizona State University; the Massachusetts Institute of Technology; NSF O/IR Lab; the University of Chicago; Adolfo Ibáñez University; Bern University; Lund University; Paris Observatory; the University of Exeter; and Xiamen University.

Kaçar's project is a first of its kind and includes the following partner institutions: Arizona State University; Stanford University; Utah State University; the University of Minnesota; the University of Tennessee, Knoxville; Iowa State University; and the University of Alberta.

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