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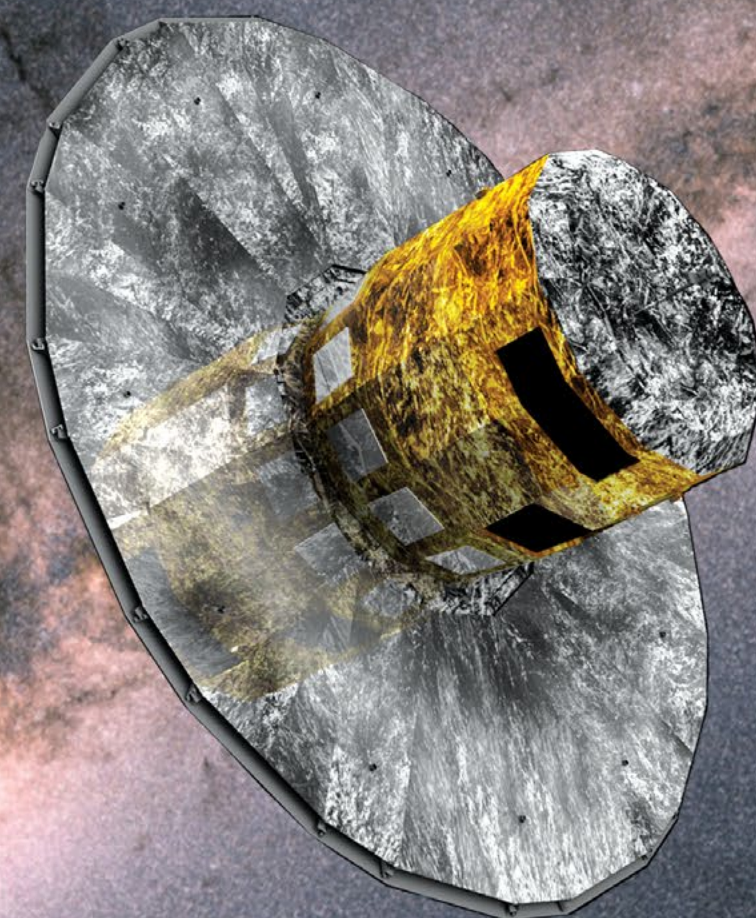
Space & Physics

The Hidden History of the Milky Way

A NEW FLOOD OF STAR DATA REVEALS A GALACTIC COLLISION SOME EIGHT TO 11 BILLION YEARS AGO



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OPINION: WHEN E.T. COMES KNOCKING, BE KIND

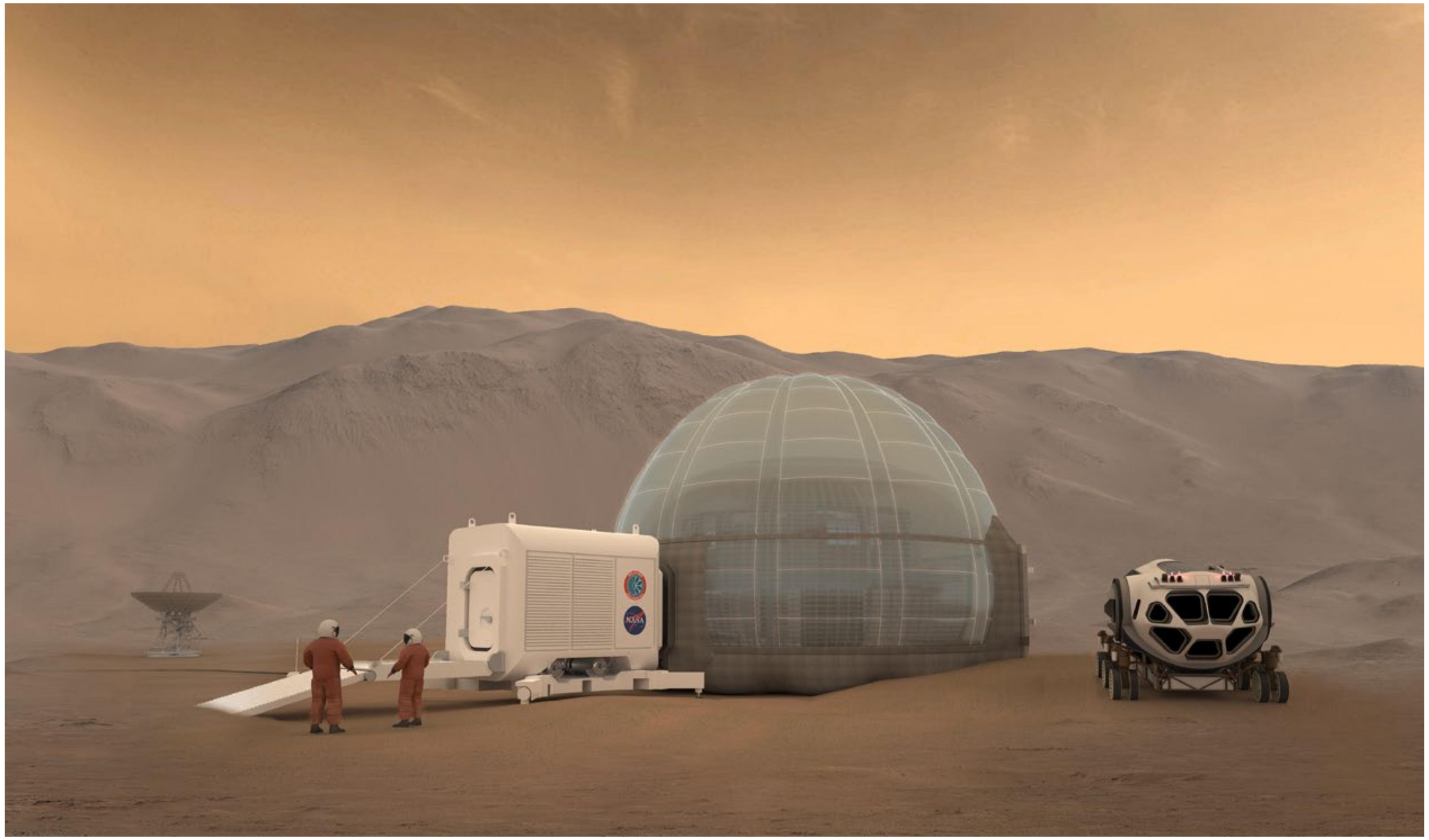
WITH COVERAGE FROM
nature

Mark Blenner is the McQueen-Quattlebaum Associate Professor of Chemical and Biomolecular Engineering at Clemson University. His research group engineers yeast and other cells to make value-added products using renewable and waste substrates. His work has been supported with funding from NASA's Space Technology Research Grants program.

OBSERVATIONS

Microbes Might Be Key to a Mars Mission

Engineered yeast could turn waste into food, plastics and other essentials



NASA, CLOUDS AO AND SEARCH WIKIMEDIA

Picture a group of adventurous companions setting out into the great frontier to explore a barren, wild land. They must bring only the most important things they'll need to survive on their own. Every ounce of weight they decide to take with them means another ounce they must transport. It sounds like an extreme backpacking trip, but I'm actually talking about a future mission to the surface of Mars.

We take for granted all the things we have on Earth that support human life—air for breathing, water for drinking and nutrients in the soil that allow us to grow food. On Mars, however, astronauts will need to bring their own life support systems, which can be prohibitively costly to transport. Without a lightweight flexible technology that can manufacture a variety of products using limited resources, the first Mars explorers won't survive their journey.

Typically, microbes are considered a threat to space missions because they could cause illnesses. But nonpathogenic microbes might in fact be part of the solution for getting to Mars. Microbes can convert a wide variety of raw materials into a large number of essential products. Using engineering principles, synthetic biology can be harnessed to turn microbes into tiny programmable factories.

I began to study yeast as way to make chemicals when I joined the chemical and biomolecular engineering department at Clemson University in 2012. My research group works with a type of yeast called *Yarrowia lipolytica*, which efficiently makes fatty acids in the form of trigylcerides from a wide variety of low-value waste streams. Genetic engineering makes it possible to add genes from other organisms to enable production of derivatives of fatty acids, such as biofuels, precursors for adhesives and nutraceuticals.

My students and I began to think about where wastes were abundantly available; where their storage posed a significant problem; and where yeast-derived products would be in short supply. It turns out, unsurprisingly, that human waste is both problematic and unavoidable: it generates more than half of the waste on a typical mission. This includes, most obviously, urine and feces. But it also includes carbon dioxide and water from crew respiration, perspiration and hygiene; food waste, packaging waste and even dead skin cells. It sounds pretty gross, but we wondered if we could engineer *Yarrowia lipolytica* to make mission-critical fatty acid–derived products from these materials.

We used synthetic biology to “cut and paste” genes from algae and plants into our yeast. This enabled them to make omega-3 fatty acids like eicosapentaenoic acid (EPA), a bioactive component of fish oil that has been shown to prevent bone density loss in astronauts. In a separate strain, we inserted a gene from bacteria that convert fatty acids into polyesters called polyhydroxyalkonates (PHAs). By engineering the fatty acid metabolism pathway, we can tune the properties of the individual PHA units so we can make plastics with properties matched to their application. This may be important for a Mars mission as a way to make the polymers needed for 3-D printing parts or tools that break or are lost.

Microbes need to eat, and our next challenge was how to feed them. As a source of carbon, we chose carbon dioxide, produced by crew members at a rate of over one kilogram per day. Carbon dioxide is also abundantly available on Mars, making up more than 97 percent of the atmosphere. Since our yeast does not directly consume carbon dioxide, we use a fast-growing cyanobacteria that converts the carbon dioxide into sugars and cell biomass for our yeast.

The other major element needed for growing yeast is nitrogen, which is available in the form of urea in human urine. In a recent publication in *Applied Microbiology and Biotechnology* we reported the efficient use of the urea by *Yarrowia lipolytica*. That’s no surprise: this yeast has genes that are similar to those in microbes that colonize the human urinary tract and eat urea.

While microbes are not the only solution, they should continue to be developed for a future Mars mission. As we get better at designing microbes to make specific products, meeting the needs of Mars-bound pioneers may become as easy as backpacking here on Earth, but we still have many miles to go.