Are We Alone?

Odds are, we aren't the first advanced civilization in the universe, says a Rochester astrophysicist.

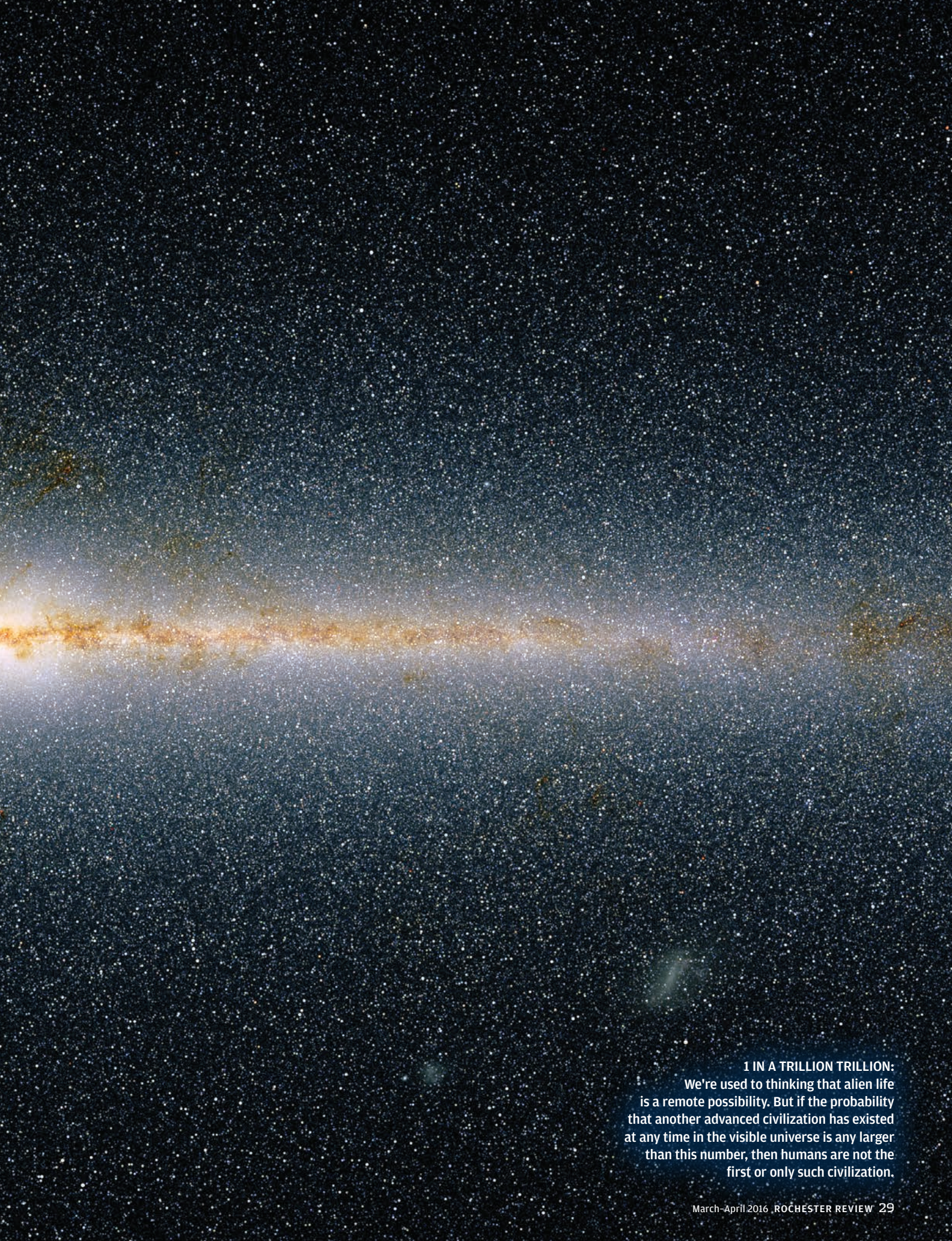
By Leonor Sierra with Karen McCally '02 (PhD)

Are humans unique and alone in the vast universe?

It's a question humans have asked for millennia. But it hasn't been until recently that there's been any scientific framework in which to even begin to posit answers.

In the early 1960s, astrophysicist Frank Drake, now professor emeritus of astronomy and astrophysics at the University of California, Santa Cruz, developed an equation that could theoretically estimate the number of advanced civilizations existing in the Milky Way galaxy. Drake intended his equation to offer a guide for research. At the time, astrophysicists didn't have nearly the knowledge it would actually take to come up with a value for the elusive N: the number of advanced civilizations (which Drake defined in practical terms as civilizations emitting detectable electromagnetic waves) that were likely to inhabit the galaxy.

J. CARPENTER, T. H. JARRETT, AND R. HURT/TWO MICRON ALL SKY SURVEY, UNIVERSITY OF MASSACHUSETTS AND THE INFRARED PROCESSING AND ANALYSIS CENTER OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY



1 IN A TRILLION TRILLION: We're used to thinking that alien life is a remote possibility. But if the probability that another advanced civilization has existed at any time in the visible universe is any larger than this number, then humans are not the first or only such civilization.

Drake Equation (1961)

$$N = R_* \times f_p \times$$

The number of technologically advanced civilizations in the Milky Way galaxy

The rate of formation of stars in the galaxy

The fraction of those stars with planetary systems

Tale of Two Equations

In 1961, astrophysicist Frank Drake developed an equation to estimate the number of advanced civilizations likely to exist in the Milky Way galaxy. The Drake equation has proven to be a durable framework for research, and space technology has advanced scientists' knowledge of several variables. But it's been impossible to do anything more than guess at variables such as L, the probable longevity of other advanced civilizations.

In new research, Adam Frank, a professor of physics and astronomy at Rochester, offers a new equation to address a slightly different question: What is the number of advanced civilizations likely to have developed over the history of the observable universe? Frank's equation draws on Drake's, but eliminates the need for L.

Frank Equation (2016)

$$A = N_{ast}$$

The number of technological species that have formed over the history of the observable universe

The number of habitable planets in a given volume of the universe

Among the unknowns was the number of planets in the Milky Way. And as long as that was unknown, it would also remain unknown what percentage of such planets—or exoplanets, as they're called—would likely have environments suitable for life.

Scientists have made enormous progress toward estimating both of those variables, thanks to NASA's Kepler Mission and other advances in astronomy. The Kepler space observatory was launched in March 2009 with the goal of exploring the Milky Way's planetary systems in order to find habitable planets. Using data from that mission, astrophysicists can now achieve reliable estimates for both those variables. But roadblocks remain.

And in new research, Adam Frank, a professor of physics and astronomy at Rochester, and his coauthor Woodruff Sullivan of the University of Washington have advanced a means to overcome the obstacles.

"The question of whether advanced civilizations exist elsewhere in the universe has always been vexed with three large uncertainties in the Drake equation," says Frank. "We've known for a long time approximately how many stars exist. We now know that roughly one-fifth of stars have planets in 'habitable zones,' where temperatures could support life as we know it."

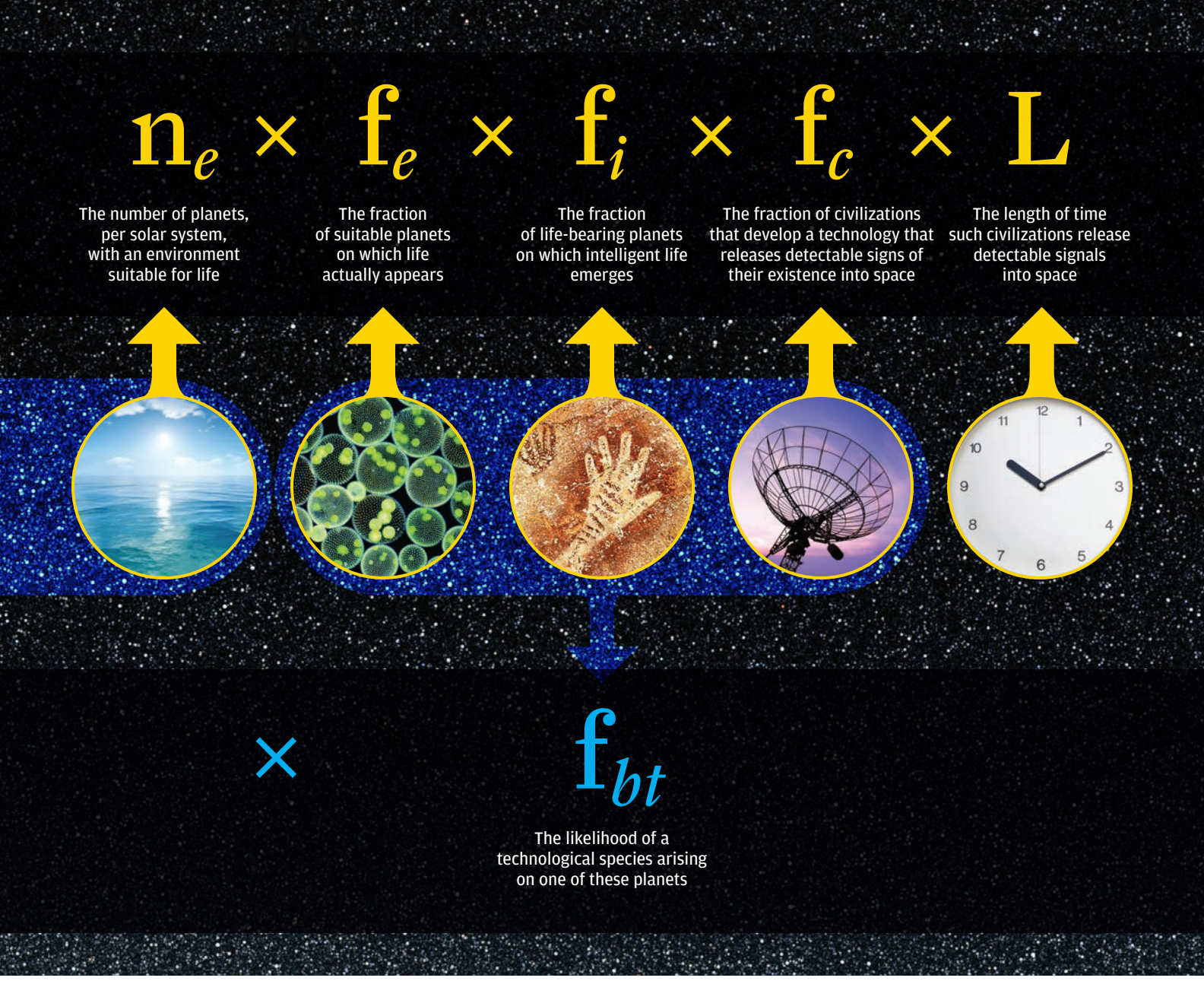
But the Drake equation requires an estimate for how often planets suitable for life actually develop life. Second, it requires an estimate for how often life evolves into intelligent life, and how often intelligent life develops into advanced civilization. And most troublesome of all, according to Frank, the Drake equation requires an estimate for how long advanced civilizations are likely to persist. "The fact that humans have had rudimentary technology for roughly 10,000 years doesn't really tell us if other societies would last that long," Frank says.

Frank and Sullivan respond to these dilemmas by posing a slightly different question. "Rather than asking, how many civilizations may exist now?" says Frank, "we ask, are we the only technological species that has ever arisen?"

By restating the question, Frank and Sullivan eliminate the need to know any information about civilization longevity. Frank calls the new question the "cosmic archaeological question"—how often in the history of the universe has life evolved to an advanced state?

Of course, that still leaves huge uncertainties in calculating the probability for advanced life to evolve on habitable planets. It's here

STEVE BOERNER (GRAPHIC); NASA (MILKY WAY, PILLARS OF CREATION, SATURN);



that Frank and Sullivan flip the question around. Rather than guessing at the odds of advanced life developing, they calculate the odds *against* it occurring. In other words, what are the odds that humanity, here on Earth, is the only advanced civilization ever to develop in the entire history of the observable universe?

"Of course, we have no idea how likely it is that an intelligent technological species will evolve on a given habitable planet," says Frank. "But using our method, we can tell exactly how low that probability would have to be for us to be the only civilization the universe has produced."

So how unlikely is it in a universe consisting of an estimated 10 billion trillion stars, or even among the Milky Way's estimated 100 billion? Applying the new exoplanet data to the universe's 2×10 to the 22nd power stars, Frank and Sullivan find that human civilization is unique in the cosmos only if the odds of a civilization developing on a habitable planet are less than about one in a trillion trillion, or one in 10 to the 24th power.

"One in a trillion trillion is incredibly small," says Frank. "Think of it this way: before our result you'd be considered a pessimist if you imagined the probability of evolving a civilization on a habitable planet were one in a trillion. But according to our results, one chance in a trillion implies that what has happened here on Earth with humanity must have happened a trillion other times over cosmic history. A trillion other civilizations doesn't sound so pessimistic."

Frank cautions against dreams of extraterrestrial communication. "The universe is more than 13 billion years old. That means that even if there have been a thousand civilizations in our galaxy alone, if they live only as long as we have been around—roughly 10,000 years—then all of them are likely already extinct. And others won't evolve until we are long gone."

But that reality doesn't diminish the profound scientific and philosophical significance of the new result.

"Given the vast distances between stars and the fixed speed of light, we might never really be able to have a conversation with another civilization anyway. If they were 50,000 light-years away, then every exchange would take 100,000 years to go back and forth. So from a fundamental perspective the question is, has it ever happened before? It's not just, has it happened recently and nearby? Our result is the first time anyone has been able to set any empirical answer for that question. And it turns out that it's pretty likely we are not the only time intelligence and civilization has evolved." ®

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