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Is anybody out there?

News from Venus has raised fresh hopes of finding alien life right next door – but that is the easy bit. What are the chances we will find intelligent life elsewhere in the universe, asks **Dan Falk**

EARTH makes life look easy. Our home planet is teeming with some 9 million species, including at least one smart enough to contemplate intelligent life existing elsewhere in the universe. We love to think it is out there – that we aren't a one-off, alone in an unimaginably vast cosmos.

A string of discoveries has boosted the idea that extraterrestrial life might be abundant. The growing catalogue of exoplanets, many orbiting within the "habitable zone" of their host stars, points to seemingly ample real estate on which life might be found. Closer to home, subsurface oceans on icy moons in the outer solar system hint that some life-friendly conditions might be commonplace. And then there is last month's discovery of phosphine in the poisonous atmosphere of Venus (see page 12), which suggests life might flourish even in seemingly hostile places.

With all that in mind, it is easy to imagine that intelligent life has evolved on at least one planet around one of the 100 billion or so stars in our galaxy. So easy, in fact, that we tend to assume, given the vastness of the visible universe, that there must be other technological civilisations out there. Yet we haven't heard from them. Why?

In the absence of evidence from deep space, some astronomers have recently returned their focus to Earth – and the only example of intelligent life we have – for a fresh look at the question. What they found meshes with what biologists have been whispering for a while: that anyone expecting to hear from an alien civilisation should settle in for a long wait.

A famous formula

For all its lack of success, the search for extraterrestrial intelligence (SETI) has never lacked for optimism. For decades, SETI researchers have swept the skies with radio telescopes in the hope of finding messages from another technological civilisation. But the truth is that we have no idea if there is anybody out there.

To estimate the number of intelligent civilisations capable of transmitting or receiving radio signals within the Milky Way, we often fall back on a formula drawn up by astronomer Frank Drake in 1961. The Drake equation multiplies seven variables, starting with the rate of star formation in the galaxy, the fraction of those stars with orbiting planets and the fraction of those planets that are habitable. Thanks largely to the Kepler space telescope, which discovered thousands of exoplanets before it retired in 2018, we now know that pretty much all stars host planets, many of which could harbour life. That means we can use solid numbers for several of the Drake equation's terms.

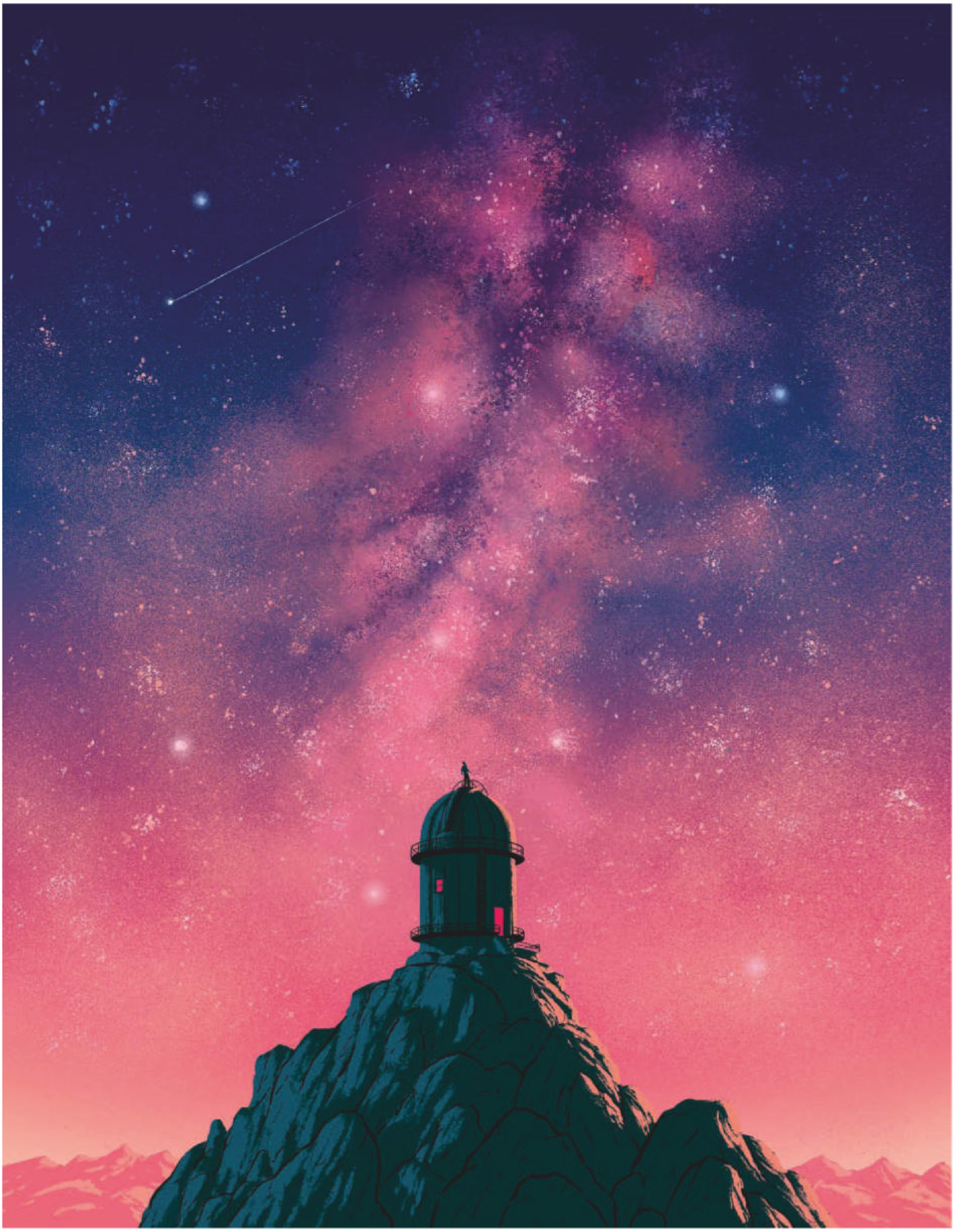
But the calculation also contains other biological variables. Here, we can do little more than guess. What is the probability that, given a habitable world, life gets started on it? And if life does arise, what are the chances that it becomes intelligent?

As things stand, these terms in the Drake equation are so poorly known that the calculation as a whole can end up spitting out numbers that suggest we are alone in the galaxy or instead that our civilisation is one of millions. It all depends on what you put in.

A conventional approach to narrowing down these probabilities would involve doing some statistics. You observe a large sample of Earth-like planets over billions of years to see how frequently life arises and how often any life that does emerge becomes intelligent. The trouble is that we have a sample size of one – Earth – and a grand total of two data points concerning it. We know that life appeared on our planet fairly quickly after it was formed some 4.5 billion years ago – within the first 300 to 900 million years – while intelligence is a much more recent development.

But there is another way to approach probabilities, and it could change how we think about the odds of finding alien civilisations we could communicate with.

Bayesian statistics takes its name from 18th-century mathematician Thomas Bayes. He came up with a way to calculate the probability of a future event based on what ›



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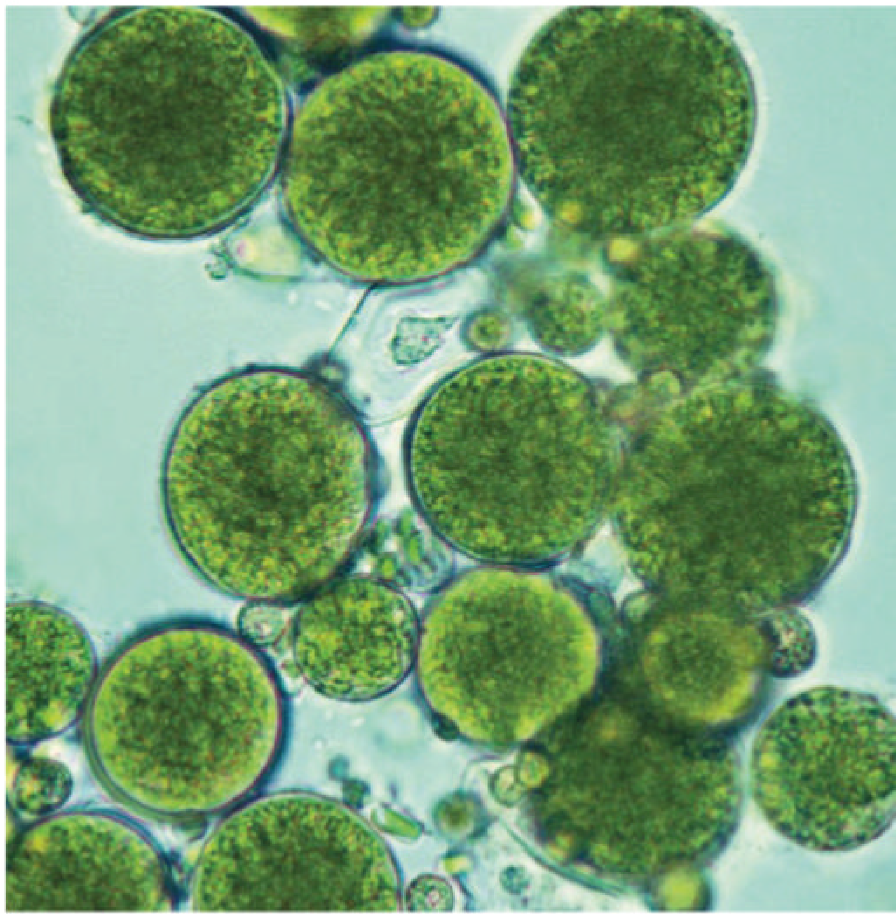

The jump from simple to complex life may have been a complete fluke

has come before by constantly updating the odds as new information becomes available. Roughly put, probability depends not only on the data you have, but also on your prior assumptions. So Bayesian statistics provides a clever way to calculate probabilities from limited data.

Prior beliefs, or "priors", are crucial. In this case, they involve our beliefs about how quickly life appeared on Earth after its formation and how quickly intelligence followed. Once we select values for these priors, we can draw conclusions about the relative likelihood of these processes playing out again – either on Earth, if we turned back the clock, or on other similar planets.

In 2012, David S. Spiegel and Edwin Turner, both then at the Institute for Advanced Study in Princeton, New Jersey, were the first to apply a Bayesian approach to life's early appearance on Earth. They relied on so-called uniform priors: if you divide our planet's history into uniform chunks (each spanning 100 million years, say), you can then assert that life is equally likely to get started in any one of those chunks. But they described their results as "inconclusive". The early appearance of life on Earth hinted at its emergence being relatively common, but they were unable to draw a stronger conclusion.

Now, David Kipping, an astronomer at Columbia University in New York, has found a way to perform the calculation independently of the choice of priors, promising a more robust result. Roughly speaking, this boils down to betting that the probability of life appearing on a habitable planet and the probability of life evolving to become intelligent both ought to be either close to 0 (meaning it would never happen) or to 1 (meaning it would always happen), but not some arbitrary value in between. "It would be really odd if 50 per cent of Earth-like planets, with the exact same conditions as Earth, ended up with life on them and 50 per cent didn't," says Kipping. "You'd expect that either they pretty much all do or they pretty much all don't."

This produces four general scenarios that Kipping argues are more probable than all the others: life and intelligence are both rare; life and intelligence are both common; life is rare, but almost always gives rise to intelligence; or life is common, but rarely gives rise to intelligence.

Into this framework, he inserted the numbers. Just as there is some uncertainty about when life first got established, so the question of when intelligence appeared is open to debate. Did it arise with tool-using hominins a few million years ago or with the advance of modern science a mere 400 years ago? Drake himself saw the key moment as the development of radio technology, which happened little more than a century ago. In fact, Kipping points out that the date you take hardly matters: a few million years over a multibillion-year timescale makes little difference to the final result.

Uncommon intelligence

Crunching the numbers, Kipping found that the "life is common, but rarely gives rise to intelligence" scenario is about nine times more likely than the "life and intelligence are both rare" scenario. Remarkably, he also found that the "life is common" conclusion follows no matter what priors you take. Ultimately, Kipping concluded that the pair of intelligence-is-rare scenarios are favoured by three to two over the pair of intelligence-is-common ones.

"To me, that's so close to 50:50 that it's not worth getting too hung up on," he says. "It's a very 'soft' preference." Yet it does tell us something. Given a limited amount of data and some sophisticated maths, our expectations for finding intelligence beyond Earth are nudged "very gently toward a pessimistic view", says Kipping. "My bet is that life is common, but intelligent life may be rare."

This may be a minority position for astronomers, but it is something that biologists have been suggesting for some time: that we may have been overestimating the likelihood of life taking hold on habitable planets and the chance that life, once it appears, gives rise to intelligence.

Matthew Cobb, a biologist at the University of Manchester, UK, has argued that people have been too eager to assume that life has some sort of tendency towards increasing complexity – never mind intelligence. In a chapter he contributed to the 2017 book *Aliens: The world's leading scientists on the search for extraterrestrial life*, Cobb points out that there are myriad hurdles to get from simple life forms to intelligence, any one of which might never be cleared if Earth's history played out again.

The jump from simple organisms to multicellular eukaryotic organisms

L-R: RED RESCHKE;HANS STRAND;MARCO BOTTIGELLI/GETTY IMAGES

consisting of complex, membrane-bound cells with a central nucleus, for example, may have been a complete fluke. It required two simple cells to bump into one another in a particular way, one absorbing the other – an event of "mind-boggling improbability", says Cobb. Similarly unlikely, he thinks, is the development of culture and intelligence. He notes that it is easy to imagine an alternate Earth in which, say, the scientific revolution never happens. All of which suggests we should exercise caution, if not outright pessimism, when it comes to estimating the chances that intelligence and ultimately technological civilisations evolved elsewhere.

But wait. What if evolution, even though it has no preferred "direction", nonetheless converges on certain useful characteristics – like intelligence, for instance? Wouldn't that boost the odds? After all, evolution has found multiple pathways leading to animals with eyes and wings. So perhaps evolution isn't quite as haphazard as it first seems. One might imagine that intelligence is at least as advantageous as seeing or flying. Might we then expect intelligence to appear often, wherever life has taken hold?

Cobb isn't convinced. "Human intelligence had a selective advantage for us," he says. "But there's no tendency in animal life for increased intelligence." Take fish. They first appeared about 450 million years ago, but we wouldn't describe them as intelligent life. "They're pretty smart – but they're fish," says Cobb. In the end, he leans towards a position similar to Kipping's: while various sorts of primitive life might be commonplace, intelligence may be much rarer.

"We may have overestimated the chance that life, once it appears, evolves intelligence"

Charles Lineweaver, an astrobiologist at the Australian National University in Canberra, goes further. He believes that when we define intelligence as some sort of generic quality, we are being disingenuous. What we really mean, he says, is human-like intelligence. That is a problem because such intelligence is a species-specific attribute of *Homo sapiens*. "And as soon as you take that term 'species-specific' seriously, there's no chance in hell that you should expect to find [intelligence] elsewhere," he says.

Of course, none of this proves that we are alone in the cosmos. Space is, after all, awfully large. With at least 100 billion planets in the Milky Way and trillions beyond, we still might expect a few technological civilisations to have cropped up over the aeons, in spite of the biological hurdles. But where making contact is concerned, we have to consider whether those civilisations have mastered radio technology, as well as the final term in the Drake equation: the length of time such civilisations last.

In June 2020, just a few weeks after Kipping's study was published, Tom ›

The Allen Telescope Array in California listens for messages from alien civilisations

SETH SHOSTAK/SETI INSTITUTE

Westby and Christopher Conselice at the University of Nottingham, UK, used a modified version of the Drake equation to estimate that there are at least 36 civilisations in our galaxy. They arrived at this figure by assuming that, given a planet hospitable to life, intelligent life typically appears after about 5 billion years, because that is how it played out here on Earth. Then they expressed this as a fraction of the length of time for which those hospitable conditions persist – roughly, the lifetime of the host star. They also assumed that once an intelligent civilisation arises, it lasts for at least 100 years. If they typically last longer than this, the pair's estimate for the number of civilisations in the Milky Way would increase.

All of which sounds distinctly optimistic, but the result was greeted with scepticism from many in the field. That is partly because in Westby and Conselice's estimation, the number of civilisations in the galaxy could be anything from four to 211. "The error bars are too huge to really mean anything," says Angelle Tanner, an astronomer at Mississippi State University. Another concern is that the analysis amounts to plugging best-guess numbers into the Drake equation, something astronomers have been doing for decades.

Long-distance call

But suppose there really are 35 other civilisations in the Milky Way. In that case, the average distance between them works out to about 17,000 light years, the pair conclude, putting a damper on any hopes we might have for back-and-forth communication. "It would take 17,000 years for any signal to reach us," says Conselice. "And even if we're able to understand it, any signal we send back would take another 17,000 years – and then another 17,000 years for them to reply. If there are thinking things out there, we're probably never going to make contact with them."

The idea that we will is perhaps conditioned. "I think there's a degree of cultural preprogramming from shows like *Star Trek* and *Star Wars* that have definitely geared us up to that expectation," says Kipping. Humans are also inherently social animals, he adds. Collectively, we yearn to reach out to some other species that is our intellectual equal. So when we ask if such creatures are out there, somewhere, "I think we're biased toward wanting the answer to be 'yes'", he says.

"If there are thinking things out there, we are probably never going to make contact"

In any case, even the sceptics believe that SETI, which is gradually moving from the fringes to be recognised as a branch of mainstream science, is a worthwhile pursuit. You don't make discoveries by calculating probabilities, so reckoning the chances of success shouldn't deter astronomers here from searching for messages sent by their counterparts on other planets. What's more, the sheer scale of the implications were the SETI project to succeed compel us to keep looking even in the face of long odds – and who knows what else we might discover along the way.

It remains to be seen what we might find on Venus, but perhaps the new hints of life there provide fresh support for a line that Lineweaver likes to quote, from the late biologist J. B. S. Haldane: "The Universe is not only queerer than we suppose, but queerer than we can suppose." ■

Dan Falk (@danfalk) is a science journalist based in Toronto. His books include *The Science of Shakespeare* and *In Search of Time*