OCTOBER/NOVEMBER 2019 | SCIENTIFICAMERICAN.COM

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# Mysterious Neutrinos

RESEARCHERS ARE ONE STEP CLOSER TO DETERMINING HOW HEAVY THE UNIVERSE'S LIGHTEST MATTER PARTICLE MIGHT BE

*Plus:*

HOW MACHINE LEARNING CAN BOOST ASTRONOMY

A NEW LOOK INTO THE EARLY UNIVERSE

FUTURE MISSIONS TO THE OUTER PLANETS

WITH COVERAGE FROM nature

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OBSERVATIONS

# Can Mars Be Made Habitable in Our Lifetime?

**It could be possible, at least to some degree, with a novel system involving aerogel**

It's a very poorly kept secret in planetary science that many of us first got inspired to join the field by reading science fiction. For many of us who study Mars, Kim Stanley Robinson's 1990s Mars trilogy, which describes the colonization and eventual terraforming of the Red Planet, was particularly influential. But rereading these books in 2019, I noted that much of what he imagined looks pretty far-fetched—we're still a long way from landing the first human on Mars, and terraforming the planet to make it habitable seems like a very distant dream.

Serious scientific ideas for transforming Mars into an Earth-like planet have been put forward before, but they require vast industrial capabilities and make assumptions about the total amount of accessible carbon dioxide on the planet that have been criticized as unrealistic. When we started thinking about this problem a few years ago,

NASA, JPL-CALTECH AND MSSS

therefore, we decided to take a different approach. One thing you learn quickly when you study Mars's past climate, as we do in our usual research, is that while it was intermittently habitable in the past, it was never really like Earth—it has always been a unique and alien world. So when we're thinking about how to make Mars habitable in the future, perhaps we should also be taking inspiration from the Red Planet itself.

One natural process on Mars—the so-called solid-state greenhouse effect—is of particular interest, as it is capable of intensely heating layers of ice just below the surface in Mars's polar caps every summer. This effect occurs when visible light is transmitted into the interior of a thermally insulating material, after which the heat becomes trapped and dramatic warming can occur.

Inspired by this process, as well as by a question I posed a few years ago for a graduate class on planetary climate (never say that teaching can't help with research!), we set out to see how much warming could be created on Mars by thin layers of translucent solid material on the surface. To do our experiments, we used silica aerogel, an exotic material that is incredibly insulating, very low density (it's over 97 percent air) and almost transparent to visible light, making it an ideal candidate for creating strong solid-state greenhouse warming.

Silica aerogel is already used by NASA to insulate the insides of Mars rovers, among other things. As we show in our paper via a combination of lab experiments, modeling and first-principles theory, we found that a two- to three-centimeter-thick layer of this stuff placed on or not far above the Martian surface would be sufficient to keep the layer below permanently warm enough to grow algae or plants and to block most hazardous UV radiation. If we're happy to start locally, making Mars habitable might therefore be a far more achievable goal than has previously been thought.

What are the next steps? Our paper demonstrates that the basic physics of this idea is sound, but there is still lots of work to be done in understanding how actual habitats could be constructed on Mars with this approach. Silica aerogel is quite fragile, so to allow for robust shields and control interior pressure it would need to be modified or combined with some other materials. There is also the question of how to supply silica aerogel on Mars. It's very light, which is favorable for transporting it from Earth, but eventually we'd want to make it on the surface.

One standard industrial approach involves a high-pressure $CO_2$ drying step, which could use $CO_2$ supplied from the atmosphere. But it is notable that some organisms on Earth are incredibly proficient at manipulating silica on nanoscales (glass sponges and diatom phytoplankton are just two examples). Speculatively, it is therefore possible that organisms could eventually be adapted to produce silica-aerogel-like material themselves, leading to a biosphere that helps to sustain its own habitable environment.

In practical terms, we next plan to focus on improving the range and sophistication of our laboratory experiments and on performing initial tests in the field. Mars is unique, but there are some inhospitable locations on Earth that are rather like it, including the Atacama Desert in Chile and the Dry Valleys in Antarctica. If we can demonstrate the feasibility of our idea at sites like these in the field, that'll go a long way toward demonstrating that it can work for real on the Martian surface.

After that, the biggest remaining hurdle will be planetary protection: any plans to put life on Mars must avoid contaminating places where there could be life already. This will be much more easily done with the regional, scalable approach we are proposing than in any global terraforming scenario, but it is still a major issue that requires very careful consideration in the future.

We're still a long way from making viable self-sufficient habitats on other planets. But for the first time, our research opens up a plausible pathway to achieve this decades in the future, rather than centuries, if we choose to do so. And we think that's something worth getting excited about.