

But on a planet orbiting a red dwarf, ice and snow will instead absorb much of the incoming light from its star. This warming effect, combined with the warming from the atmosphere, means that water-dominated planets might be more resistant to freezing over than similar planets orbiting brighter stars. If planets around a red dwarf do freeze, they might thaw out more easily over time as their host stars — like all other stars — naturally brighten. The fact that these planets are fairly resistant to climate extremes and exit those extremes easily on the rare occasion they do happen, means that they're more climatically stable and will therefore provide a greater chance for life.

Scientists are just beginning to consider the climatic impacts of different types of surface environments on red dwarf planets. The news isn't all balmy. New research finds that if temperatures within a red dwarf planet's oceans plummet below -23°C , salt could crystallize in bare sea ice, forming what is known as a *hydrohalite crust*. At infrared wavelengths, hydrohalite is brighter than snow, which means that it doesn't absorb starlight but reflects it — so much so that its presence could cool the surface more than researchers had thought possible. We still have much to learn about how different surfaces — from distinct kinds of soil and vegetation to ocean and ice — might interact with the light from red dwarfs.

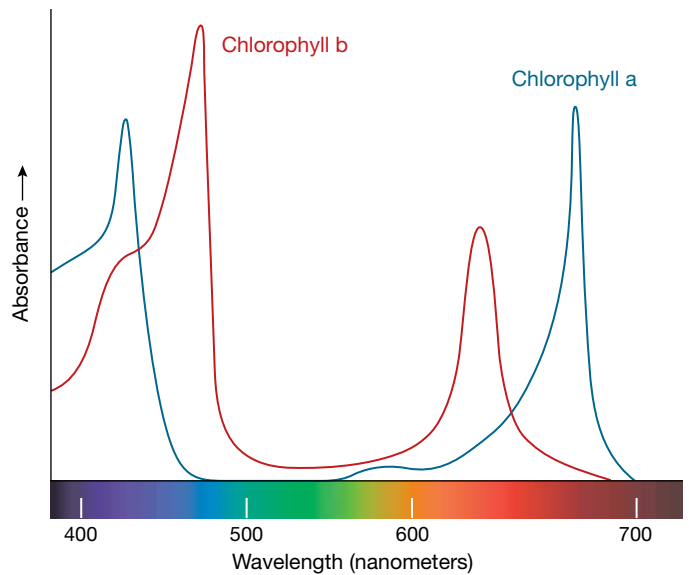
Life's Spark

It is far too soon for us to comprehensively answer the question of what kind of life might be possible on a red dwarf planet. But we can ask a more specific question: Is photosynthesis possible?

On Earth, plants use the pigment chlorophyll, which absorbs stellar light strongly in the visible range of the spectrum (400–700 nanometers), to transform sunlight and carbon dioxide into food. In the process, they produce oxygen, vital to respiration and in the production of the protective ozone layer around Earth. Given the small amount of visible light that red dwarfs emit, photosynthesis as we know it might not be possible on planets around such stars. However, life on these planets would presumably evolve to harvest the wavelengths most available. Vegetation on planets around red dwarfs might absorb radiation across a wider range of the spectrum or specifically use infrared wavelengths.

The star's flares might also provide what its calmer glow does not. Stellar flares emit radiation across the entire electromagnetic spectrum, including visible light. So it might be the case that the strong flare activity, usually thought of as damaging to life, could supply vegetation with enough visible light to conduct the kind of photosynthesis that plants do on Earth. In this scenario, the cycle governing the loss and growth of vegetation could become inextricably tied to the cycles of flare activity for a red dwarf, an unusual symbiotic prospect.

This relationship could be even more profound at ultraviolet wavelengths — and that's crucial. Researchers think that ultraviolet radiation is a necessary ingredient in the



▲ **ABSORBING LIGHT** On Earth, plants primarily use the pigments chlorophyll a and b, which absorb sunlight strongly in the visible range of the spectrum. Plants on red dwarf planets might be able to absorb light at these wavelengths as well, but they would have to rely on stellar flares, which emit light across the entire electromagnetic spectrum. The growth of vegetation would then depend not on seasons but on the red dwarf's cycles of flare activity.

chemical processes leading up to the formation of basic life. If that's true, then the paucity of ultraviolet light coming from M-dwarfs would pose an obstacle to the development of life. But flares might solve the problem: The blasts of ultraviolet photons that bombard the planet with every stellar outburst might compensate for this intrinsic deficit — providing enough light to help life emerge.

We are only at the beginning of understanding what worlds around these stars might be like. But over the next decade, we'll see space- and ground-based projects with instruments sensitive enough to observe an abundance of small terrestrial planets. NASA's Transiting Exoplanet Survey Satellite (TESS; *S&T*: Mar. 2018, p. 22) spacecraft, for example, spends 27 days staring at each patch of sky, a length of time comparable to the orbital period of planets in the habitable zones around red dwarfs. These cool, dim stars are thus the favored targets for the TESS mission. In fact, 75% of the planets TESS is expected to detect should orbit red dwarfs. The most promising planets will be close enough that follow-up studies might identify biosignatures in their atmospheres, telling astronomers that life is likely present.

If there exists a habitable planet orbiting a red dwarf, we now have a real chance of finding it.

■ **IGOR PALUBSKI** is a graduate student at the University of California, Irvine. **AOMAWA SHIELDS** is the Clare Boothe Luce Assistant Professor of Physics and Astronomy at the University of California, Irvine, and Director of the Shields Center for Exoplanet Climate and Interdisciplinary Education.