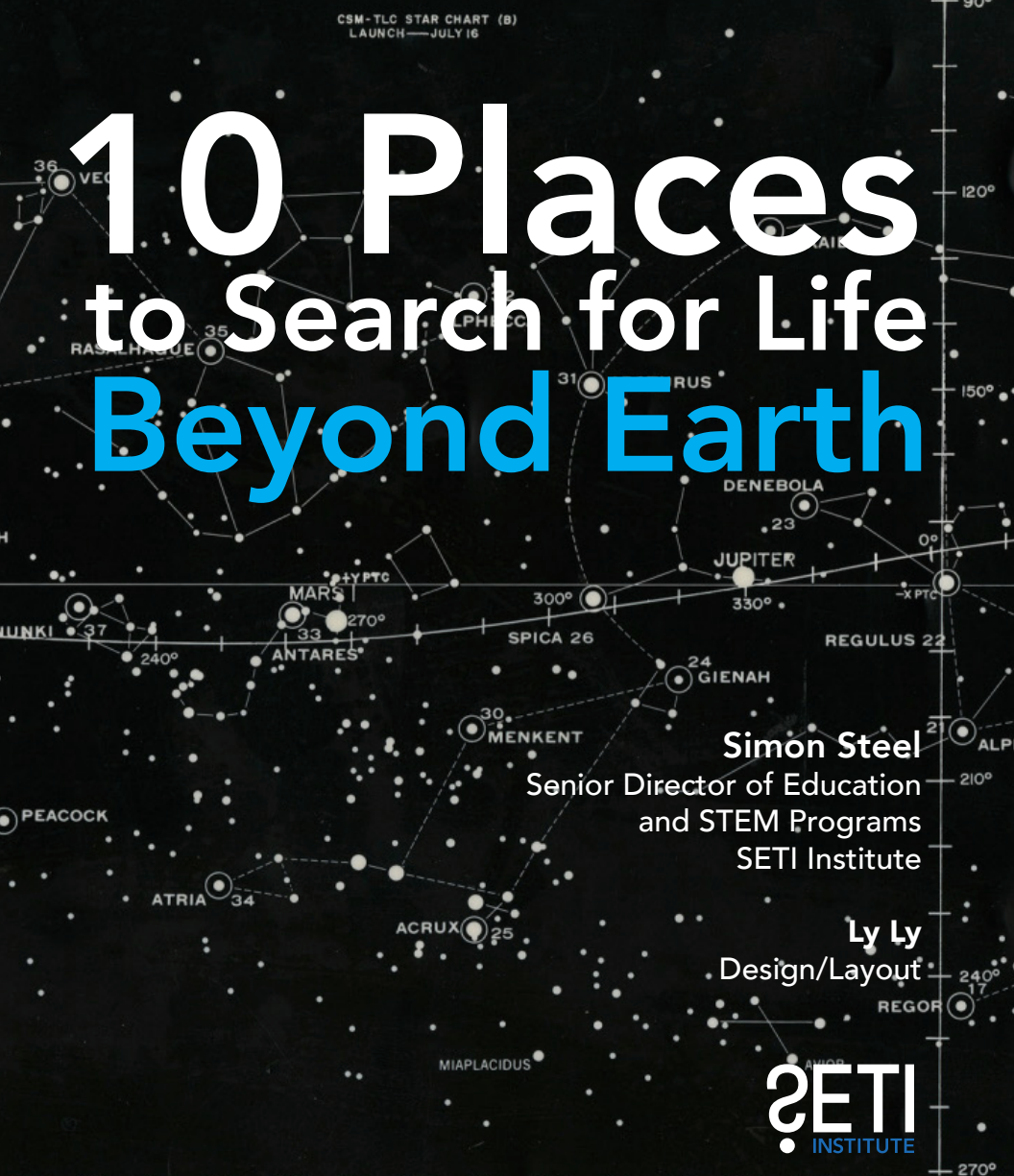


CSM-TLC STAR CHART (B)
LAUNCH—JULY 16

10 Places to Search for Life Beyond Earth



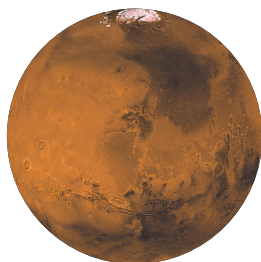
Simon Steel
Senior Director of Education
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SETI Institute

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Design/Layout




01

MARS THE RUSTY DESERT



Life on Mars has been part of the human imagination for centuries, but the planet's bone-dry surface and ghostly thin atmosphere means that it's a hostile and dangerous world. On the other hand, evidence from many orbiters and landers gives strong evidence that ancient Mars was covered in water and blanketed in a thick protective atmosphere. Could an early Mars have been the cradle of life just like young Earth, and does fossilized evidence still exist on, or beneath, the surface awaiting discovery? Could something still survive?

An aerial photograph of a large, circular crater on Mars. The crater has a prominent, dark, reddish-brown rim. The interior of the crater is filled with a lighter, tan-colored material, possibly sand or silt, and shows some internal features like smaller depressions and ridges. The surrounding Martian surface is rugged and covered in small rocks and craters.

Acidalia Planitia Mars

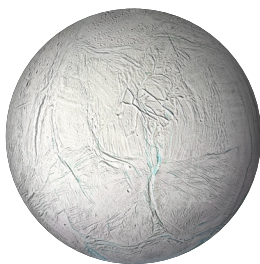
A location on Mars associated with the best-selling novel and Hollywood movie, "The Martian" This area is in the Acidalia Planitia region and in the novel and the movie, it is the landing site of a crewed mission named Ares 3.

Credit: REUTERS/NASA/JPL-Caltech/Univ. of Arizona


02

ENCELADUS

THE ARCTIC TIGER



This diminutive moon of Saturn is also its most pristine – it is a gleaming white ice-covered world whose lack of craters suggests a newly minted crust. Close passes by the Cassini spacecraft discovered plumes of water shooting out from “tiger stripe” cracks in the icy surface. These cryovolcanos indicate a liquid ocean below the ice, and chemical analysis suggests that organic molecules in this subsurface sea have all the raw materials and conditions for life in the cold, outer realms of our solar system.

An artistic illustration showing the Cassini spacecraft in the lower-left quadrant, flying towards the right. On the right side, the curved, icy surface of Saturn's moon Enceladus is visible, with a bright, glowing plume of water vapor and ice particles erupting from its south pole. The background is a dark, deep blue space with some faint, wispy clouds or dust. The lighting is dramatic, with the sun or a light source behind the moon, creating a strong silhouette and highlighting the texture of the moon's surface and the intensity of the plume.

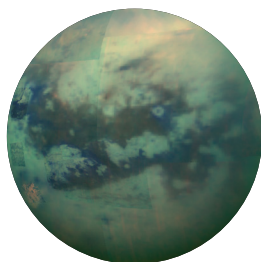
This illustration shows NASA's Cassini spacecraft diving through the plume of Saturn's moon Enceladus, in 2015.

Credit: NASA/JPL-Caltech

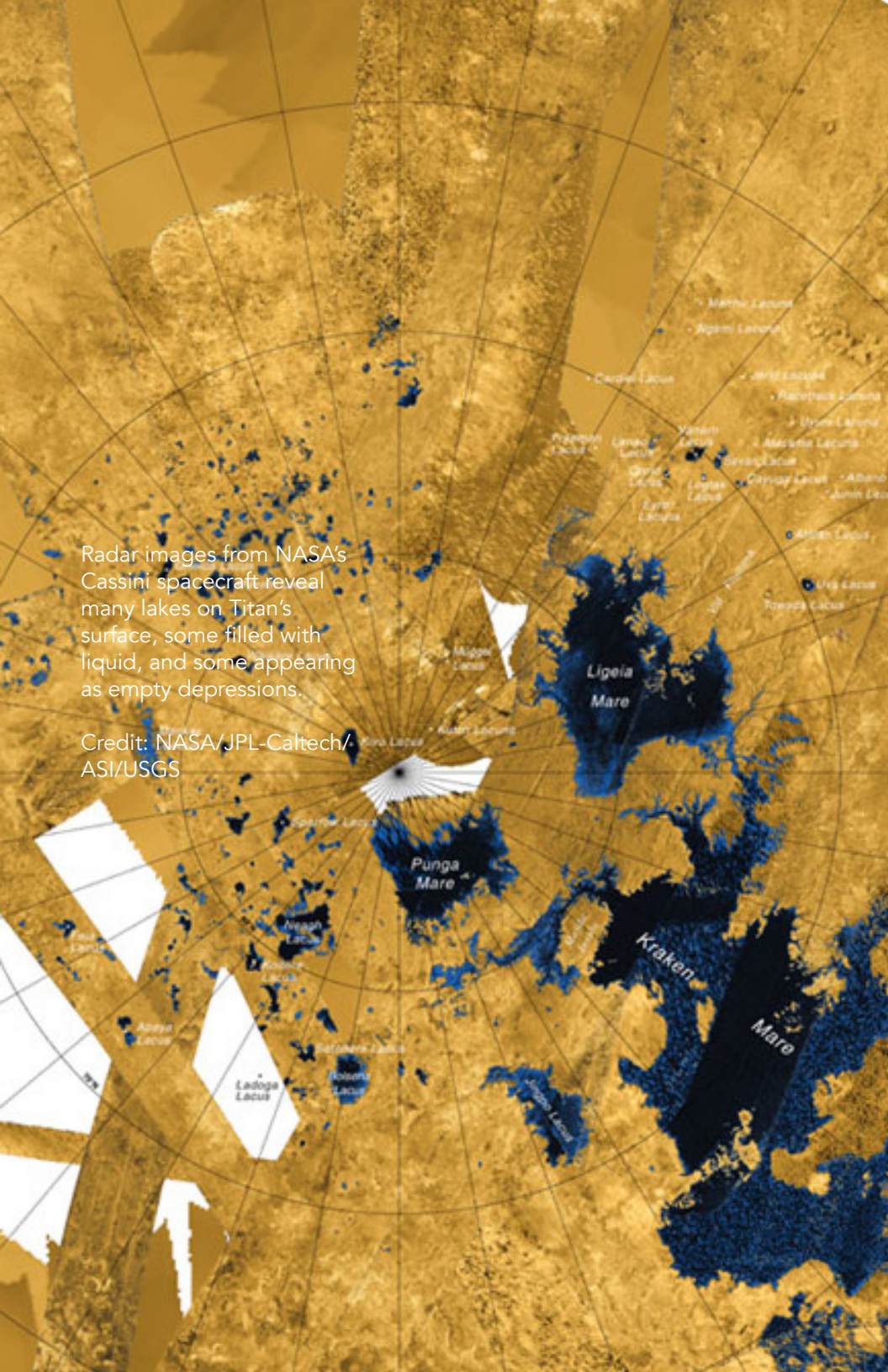
03

TITAN

PRIMORDIAL EARTH



This is the second-largest moon in the Solar System and is bigger than the planet Mercury. It is the only world other than Earth known to have stable liquids on its surface. But with an average surface temperature -180°C , these are lakes of liquid methane, not water. So this cold, distant satellite, choked with organic smog and pelted with ethane rainstorms, may not seem like an environment conducive to life. Yet a lot of the organic ingredients are there in abundance, and lakes and pools allow those molecules to meet and mix. Titan is a perfect kitchen pantry that may be cooking up something exciting!



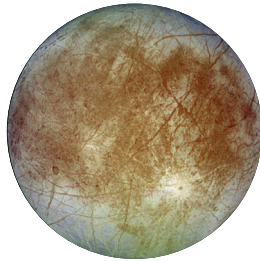
Radar images from NASA's Cassini spacecraft reveal many lakes on Titan's surface, some filled with liquid, and some appearing as empty depressions.

Credit: NASA/JPL-Caltech/ASI/USGS

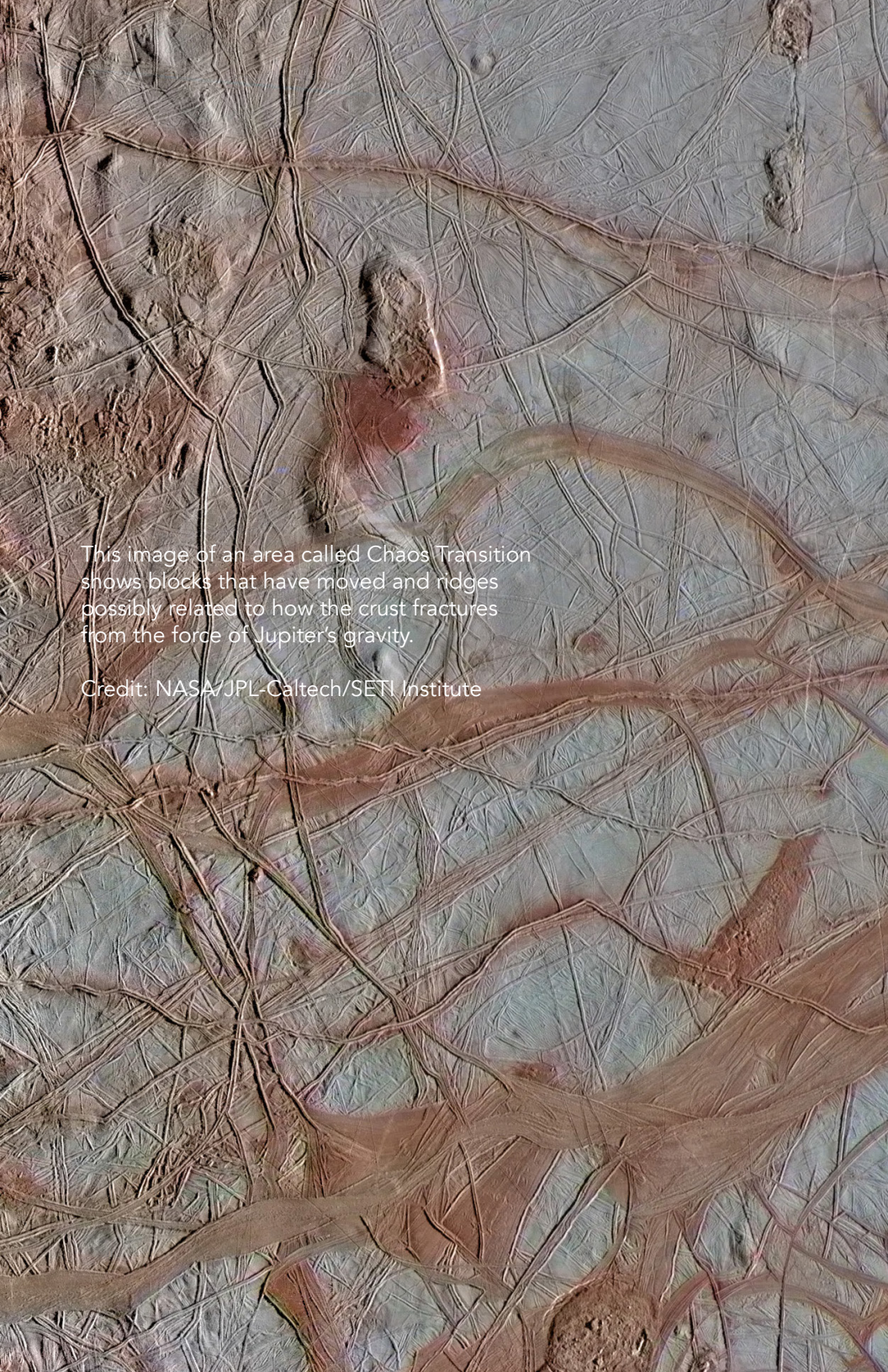
04

EUROPA

OCEAN MOON



The smallest of the four Galilean moons orbiting Jupiter, Europa, is by far the most interesting (if not as pretty as Io!). The gravitational tidal forces that stretch and squeeze this icy world have created a liquid ocean below the frozen surface, and the heat that has melted the interior may also provide the warmth and energy needed by native European life forms. We will get a closer look in the late 2020s when NASA's Europa Clipper mission arrives in the Jovian system.

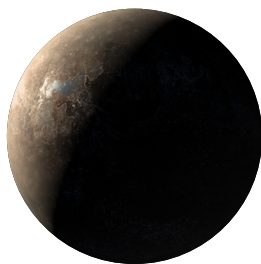


This image of an area called Chaos Transition shows blocks that have moved and ridges possibly related to how the crust fractures from the force of Jupiter's gravity.


Credit: NASA/JPL-Caltech/SETI Institute

05

PROXIMA CENTAURI b THE EXOPLANET NEXT DOOR



The triple star system Alpha and Proxima Centauri has at least one planet (a second, larger one is still tentative), but it isn't orbiting one of the two sun-like stars. Instead, it is tucked close to the tiny cool, red dwarf star Proxima Centauri. An Earth-sized world, buffeted by fierce winds from its stellar host, orbits every 11 days, and endures conditions that would be harsh for any nascent life trying to take hold. But its closeness to us, at around four light years, means that it is possible in the coming century or two, for a visit by robotic explorers from Earth, thereby beginning humanity's interstellar age.

An artist's impression of the planet Proxima b orbiting the red dwarf star Proxima Centauri. The star is a bright orange-yellow sphere on the left. The planet is a large, brownish, cratered sphere on the right. The background is a dark space filled with numerous small white stars.

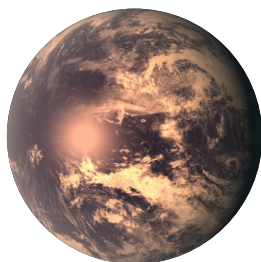
This artist's impression shows the planet Proxima b orbiting the red dwarf star Proxima Centauri, the closest star to the Solar System.

Credit: ESO/M. Kornmesser


06

TRAPPIST 1e

GOLDILOCKS WORLD (DISCOVERED 2017)



Our solar system has two Earth-size planets - the Trappist 1 system greedily has seven, three of which fall within the habitable zone of their small, red dwarf star. Being in the habitable zone means that the conditions are right for surface liquid water, should there be water, to exist and act as a fertile soup for the organic building blocks of life. Trappist 1e is the Goldilocks world of the seven, similar in mass, radius, density, surface gravity and temperature to Earth. It is one of the most potentially habitable exoplanets discovered so far.



Some 40 light-years from Earth, a planet called TRAPPIST-1e offers a heart-stopping view: brilliant objects in a red sky, looming like larger and smaller versions of our own moon. But these are no moons. They are other Earth-sized planets in a spectacular planetary system outside our own.

Credit: NASA-JPL/Caltech


07

BOYAJIAN'S STAR

ALIEN MEGASTRUCTURE (DISCOVERED 2015)



Slightly hotter than our Sun, the star studied by astronomer Tabetha Boyajian had wild and unpredictable variations in brightness. These variations triggered speculation of an extraordinary cause: alien megastructures bigger than planets and constructed to harness the energy output of the star were intermittently blocking the light from reaching our telescopes. Such structures, postulated by physicist Freeman Dyson, fell from favor as an explanation for the star's brightness variations when dust rings fitted the observations more accurately. Still, the idea of observing megastructures is now a mainstream way of searching for intelligent alien life, and Boyajian's Star paved the way.

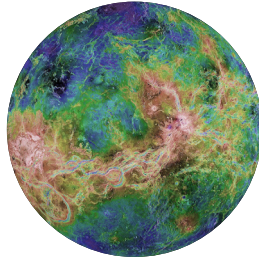
An artistic illustration of a star, KIC 8462852, also known as Boyajian's Star or Tabby's Star. The star is a bright orange-yellow sphere in the center. It is surrounded by a dark, irregular ring of dust that is thicker in some areas and thinner in others, creating a jagged, uneven appearance. The background is a deep black space filled with numerous small, distant stars of various colors (white, blue, red, yellow).

This illustration depicts a hypothetical uneven ring of dust orbiting KIC 8462852, also known as Boyajian's Star or Tabby's Star.

Credit: NASA-JPL/Caltech

08

VENUS EARTH'S TWIN



The nearest of the planets is sometimes called Earth's twin. But even with a similar mass, surface gravity, composition, and an orbit only slightly closer to the Sun than ours, Venus has an atmosphere of almost pure carbon dioxide, a surface temperature that would melt lead and pressure that would crush you, and your spacecraft, to pulp. Now rise to the top layers of the Venusian atmosphere, around 50 km above the stark surface, where temperatures and pressures are bearable and sulfuric acid clouds drift along, and you enter an environment that could provide a habitat for floating and very alien life. Maybe we don't have to look very far away after all.

A grayscale radar image of the Venusian surface. The image shows a complex network of bright, branching linear features, likely fractures or faults, crisscrossing the terrain. In the lower central portion, there is a prominent circular feature, the Wheatley crater, which has a dark, relatively flat interior and a bright, irregularly shaped rim. The surrounding surface is textured with various shades of gray, indicating different surface compositions and topographies.

Magellan radar image of Wheatley crater on Venus.

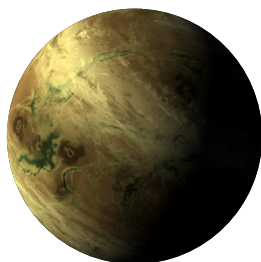
This 72 km diameter crater shows a radar bright ejecta pattern and a generally flat floor with some rough raised areas and faulting.

Credit: NASA/JPL/USGS

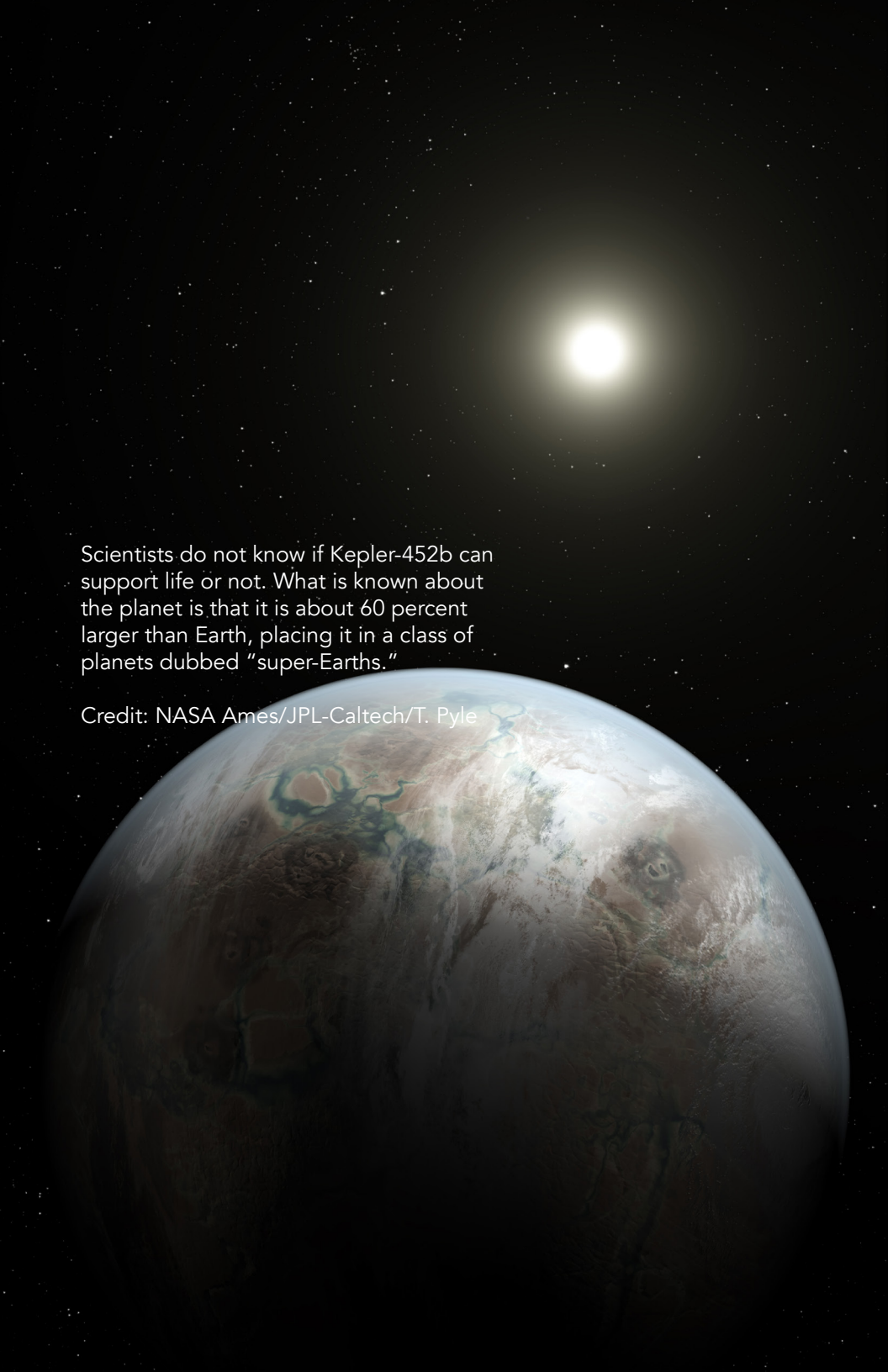
09

KEPLER-452b

EARTH 2.0 (DISCOVERED 2015)



Over 1,400 light years away is a Sun-like star, Kepler-452. Observations have sensed (but not proven) the existence of an earth-sized planet orbiting at a very similar distance from its star as ours is from the Sun. Estimates put its mass at five times that of the Earth, so it has twice the surface gravity of our world. Its star, Kepler-452, would look almost like our Sun in its sky, but Kepler-452 is over a billion years older than our Sun. If intelligent life has emerged there, it could be much more advanced and developed, or it could already have blossomed and died. Exoplanets can provide us with insights into Earth's past, or sometimes a glimpse into our distant future.

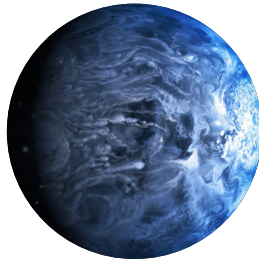
A composite image featuring a bright, glowing star in the upper right quadrant against a dark, star-filled background. In the lower half, a large, detailed rendering of a planet is shown, resembling Earth with visible continents, oceans, and a blue atmosphere. The planet's surface shows various geographical features like rivers and lakes, and it is partially illuminated by the star.

Scientists do not know if Kepler-452b can support life or not. What is known about the planet is that it is about 60 percent larger than Earth, placing it in a class of planets dubbed "super-Earths."


Credit: NASA Ames/JPL-Caltech/T. Pyle

10

GLIESE 1214b WATERWORLD (DISCOVERED 2009)



Almost hugging its diminutive red dwarf star, a year on Gliese 1214b lasts barely 36 hours. Although it is much larger than Earth - probably more like Neptune - its low density means that a large part of its volume is made up of water rather than rock. As close as the planet is to its star, a much of this water will turn to steam. While such temperatures are not conducive to the usual forms of life, discoveries of terrestrial extremophiles in water above 100 °C means that where there's water on Earth, there's life. Perhaps we shouldn't rush to discount the superheated oceans of Gliese 1214b.

The image features a large, bright orange-red star with a textured, granular surface, set against a dark background filled with numerous small, distant stars. In the lower-left foreground, a solid black circle is positioned to represent the planet GJ1214b. The star's light creates a soft, reddish glow around it.

The planet, GJ1214b, has a mass about six times that of Earth and its interior is likely mostly made of water ice. It appears to be rather hot and surrounded by a thick atmosphere, which makes it inhospitable for life as we know it on Earth.

Credit: ESO/L. Calçada



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