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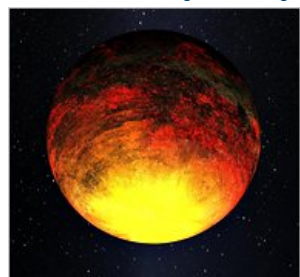
Gazing Afar for Other Earths, and Other Beings

By DENNIS OVERBYE

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MOFFETT FIELD, Calif. — In a building at NASA's Ames Research Center here, computers are sifting and resifting the light from 156,000 stars, seeking to find in the flickering of distant suns the first hints that humanity is not alone in the universe.

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NASA

NASA's idea of what the planet Kepler 10b might look like.

The stars are being monitored by a \$600 million satellite observatory named Kepler, whose job is to conduct a kind of Gallup poll of worlds in the cosmos. On Wednesday, Kepler's astronomers are scheduled to unveil a closely kept list of 400 stars that are their brightest and best bets so far for harboring planets, some of which could turn out to be the smallest and most Earth-like worlds discovered out there to date. They represent the first glimpse of riches to come in a quest that is as old as the imagination and as new as the iPad.

Over the next two or three years, as Kepler continues to stare and sift, astronomers say, it will be able to detect planets in the "Goldilocks" zones, where it is neither too hot nor too cold for liquid water.

"What we want is to find life," said Geoffrey Marcy, an astronomer at the University of California, Berkeley, who is part of the Kepler team.

William Borucki, 72, the lead scientist, who has spent the last 20 years getting Kepler off the ground, said recently in an interview in his office: "I've argued that Kepler is more important than the Hubble Space Telescope. We provide the data mankind needs to move out into space."

These are science-fiction times. Kepler is only the first step in a process that experts agree will take decades. Both NASA and the European Space Agency have laid plans for a multidecade quest — employing ever more sophisticated and expensive spacecraft — for planets and life beyond Earth.

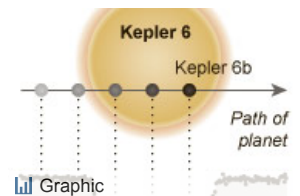
A roving robot laboratory named Curiosity will depart for Mars on a \$2.5 billion mission this fall. Astronomers

Life Out There

Combing 156,000 Stars

Articles in this series will examine the search for Earth-like planets and for new forms of life in the universe.

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Kepler's Planet Search

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Peter DaSilva for The New York Times

William Borucki, lead scientist for the Kepler satellite observatory, launched in 2009.



Peter DaSilva for The New York Times

Natalie Batalha, deputy science team leader.

argue whether the next such mission should go to [Jupiter](#)'s moon Europa, with its subsurface ocean; Saturn's moon Titan, which is coated with a methane slush; or another of Saturn's moons, Enceladus, which is spouting geysers of water from its interior.

Right now, humans cannot even summon the money or political will to get back to the Moon, let alone set sail for another star. It would take 300,000 years for Voyager 1, now on the way out of the solar system at 39,000 miles per hour, to travel the 20 light-years, or 120 trillion miles, to Gliese 581, one of the nearest planetary systems; Kepler's planets are from 500 to 3,000 light-years away. NASA and other organizations, like [the Planetary Society](#), have experimented with devices like solar sails, in which a craft is pushed by sunlight or a powerful laser, and ion drives, in which high-energy particles do the propelling.

This is more than just an intellectual exercise, scientists say. Traditional religious images of ourselves as God's creatures, or even of God, could be in for a rough time if we ever discover pond scum living by completely alien chemical rules on some moon or planet, let alone the [Borg](#) — the alien race ruled by a collective mind on "Star Trek" — inhabiting some distant realm.

Moreover, as astronomers keep reminding us, humanity will eventually lose Earth as its home, whether because of [global warming](#) or the ultimate plague or a killer asteroid or the [Sun's](#) inevitable demise. Before then, if we want the universe to remember us or even know we were here, we need to get away.

It was only in 1995 that a team of Swiss astronomers led by Michel Mayor of the Geneva Observatory discovered the first planet of another Sun-like star using what is now known as the "wobble" method. A planet gives its star a little gravitational tug as it goes around, causing the star to go back and forth, or wobble, a little as both star and planet circle the same center of gravity. They detected a wobble in the motion of the star [51 Pegasi](#) as an object about half the mass of Jupiter whipped around it every four days.

Like Olives in a Martini Glass

Over the next decade, Dr. Mayor's group and another planet-hunting team led by Dr. Marcy and R. Paul Butler of the Carnegie Institution leapfrogged each other in finding exoplanets, as they are called. More and more astronomers have joined the hunt, discovering smaller and smaller planets. Astronomers have recorded direct images of four planets swirling like olives in a martini glass around a star known as HR 8799, 130 light-years from Earth in the constellation Pegasus, and another circling Fomalhaut, only 25 light-years from Earth, in the constellation Piscis Austrinus.

There are now more than 500 planets listed on the [Jet Propulsion Laboratory's PlanetQuest Web site](#). None are habitable.

Among them is the so-called Styrofoam planet — an early trophy of Kepler's — a planet that is again half as large as Jupiter, but so puffed up by the heat of its star that it is only one-tenth as dense. Another is a planet composed almost entirely of superheated water and sometimes called the Steam World; it is known as Gliese 1214b, about 40 light-years from here in the constellation Ophiuchus.

Last year, a team of American astronomers announced that they had discovered a Goldilocks planet orbiting a dim red dwarf star at just the right distance to harbor water on its surface, making it a potential site for life. Gliese 581g, as it is known, is part of the Gliese 581 system 20 light-years from here, in Libra. But then the Swiss astronomers

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who first spotted that system were not able to find the Goldilocks planet in their own data, causing many astronomers, but not its discoverers, to doubt that the friendly 581g was real.

The Kepler project grew out of Mr. Borucki's lifelong love of space.

Mr. Borucki grew up in a small town in Wisconsin, shooting homemade rockets into the sky and praying that they did not hit a neighbor's cow.

"As a kid, this is what you wanted to do," he said.

After getting a master's degree in physics from the [University of Wisconsin](#), he went to work on the Apollo Moon program, becoming an expert in precise measurements of light. In 1984, he suggested that such measurements could be used to look for planets.

The idea is that a planet passing in front of its star would block a little of its light — very little. In the case of the Earth, the dip would amount to 84 parts per million in the Sun's light — less than a hundredth of a percent.

In 1993, when Mr. Borucki and his collaborators proposed building a satellite to do such measurements, NASA said, "If doable, it's fabulous," recalled David Koch of the University of Wisconsin, Mr. Borucki's longtime collaborator. But NASA did not think detectors could be so precise.

NASA rejected their proposal a year later, then again two years after that. "It's a wonderful thing to have someone tell you over and over again everything that is wrong with your experiment," Mr. Borucki said. That was the road to improvement.

In 1998, NASA turned the scientists down again, but gave them half a million dollars to spend on lab work.

The Kepler mission finally got the nod from NASA in 2001, but with a twist. The Ames Research Center wound up handing over management of the mission, at least until the launching, to the Jet Propulsion Laboratory in Pasadena, Calif., which developed the Vikings and Voyagers. "Here we had been competing against J.P.L. all these years," Dr. Koch said. "We got over that." Control has since reverted to Ames.

Kepler was launched from Cape Canaveral into an orbit around the Sun on March 6, 2009. Its gaze is fixed on a patch of sky about 20 full moons across near the Northern Cross, in the constellations Cygnus and Lyra, containing about 4.5 million stars. That is the neighborhood for Kepler's cosmic census. The job is simply to measure the brightness of 156,000 of those stars every half-hour, looking for the repeated dips caused by planet crossings, or "transits."

The more times a planet crosses its star, the more easily it is picked up and tagged by computers analyzing Kepler's data. And Kepler's first hits were indeed of planets that orbited their suns in a few days in close orbits that would produce oven-cleaner temperatures. The Earth, of course, takes a year to go around the Sun, so it would take two or three years for its analogue orbiting some star in Cygnus to show up in the Kepler data.

"We will find Earth-size planets in habitable zones," Dr. Marcy stated flatly last month in Seattle.

Required: Absolute Proof

There is a hitch to confirming those planets, however. Such planets would not exert enough of a gravitational tug on their suns to be detectable by the "wobble" method, the main way their masses can be measured. Instead of confirming such planets, Kepler astronomers talk about "validating" them by using high-powered telescopes to make sure, for example, that there is only one star there and not a pair of eclipsing stars or some other phenomenon that could mimic a planet's shadow.

“Earths are difficult,” Mr. Borucki said. “We’re concerned not to announce anything until we’ve proven six different ways it can’t *not* be a planet.”

As a result, more and more of Kepler’s future pronouncements will be statistical in nature. Natalie Batalha of San Jose State University, the deputy science team leader for Kepler, said it could be that they will wind up with, say, 100 planets they are 80 percent sure of, which could translate to 80 planets — useful for a census, not so helpful if you’re looking for a place to live.

“It’s a bitter pill to swallow,” said Sara Seager, an [M.I.T.](#) planetary astronomer who works with Kepler. “We will be faced with hundreds of planet candidates that may never be fully vetted as planets. We just have to live with statistics.”

But providing statistics, and not pinpointing individual planets, has always been Kepler’s prime mission. The road map to new worlds, Dr. Batalha explained, goes like this: First, Kepler figures out how abundant Earths are and how far you have to go out into the universe to find one. That information is needed to design the next step — a mission that would search the sky for Earth-like planets that are close enough to study. But at 500 to 3,000 light-years away, Kepler’s planets are too far for intense direct scrutiny.

“Once you know where they are, you study the heck out of them,” looking for spectral indications of an atmosphere and anything else, including biomarkers that are the signature of living things, Dr. Batalha wrote in an e-mail. “Everyone and their dog will be looking for biomarkers on these worlds.”

One idea for such a mission is a “starshade” that would float in front of a telescope in space and cancel out the bright light from a star, allowing its much dimmer planets to stand out.

Shading a New Telescope

Indeed, some astronomers have proposed building such a starshade for the [James Webb Space Telescope](#), Hubble’s successor, which is scheduled to be launched by NASA later this decade. “It could potentially not only image an Earth-like planet, but provide some information about its atmosphere and surface,” said David Spergel, an astrophysicist from Princeton.

Mr. Borucki likes to compare the quest for other worlds to the building of the great cathedrals, a task handed from generation to generation of believers.

And what if we finally find what we are looking for?

“The fact that we find lots of Earths just means that we have to spend a lot more money to build the next mission and go and find out if they speak English or French,” Mr. Borucki said.

If we are alone, on the other hand, “maybe we’re going to go conquer the whole galaxy,” he said. “Nobody’s out there to stop us.”

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