



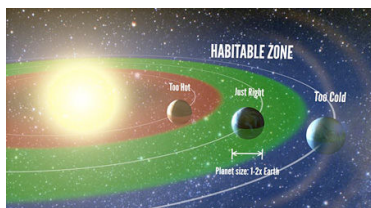
Not-So-Rare Earths

If the stars observed by NASA's *Kepler* spacecraft are statistically representative of those in our own solar neighborhood of the Milky Way galaxy, then "Earth-size planets are common around nearby Sun-like stars," conclude Erik A. Petigura and Geoffrey W. Marcy from the University of California, Berkeley and Andrew W. Howard from the University of Hawaii. They were led to that conclusion by a monumental statistical analysis of *Kepler* data completed with the help of the Carver supercomputer at the Department of Energy's (DOE's) National Energy Research Scientific Computing Center (NERSC).

Computing Earth's twin

NASA's *Kepler* spacecraft, launched into an Earth-trailing orbit in 2009, stared at some 156,000 stars in the constellation Cygnus, monitoring their brightness photometrically every 30 minutes for four years. It was searching for any minute decreases in brightness that might indicate one or more planets transiting (passing in front of) their host star as seen from Earth. (For comparison, if Earth transited the Sun as viewed another star system exactly in the plane of Earth's orbit, the Sun's light would be dimmed by 100 parts per million—a hundredth of a percent—for about 12 hours once every 365 days.)

Although *Kepler* identified some 3,000 planet candidates of all sizes orbiting stars of all colors and luminosities—some quite close to their parent star—the three authors



Artist's representation of the "habitable zone," the range of orbits where water can remain liquid on the surface of a planet.

Credit: Erik A. Petigura, Andrew W. Howard, and Geoffrey W. Marcy; artwork by Illumina Studios, LLC

wanted to find just those about the size of Earth that might be in the "habitable zone" where surface water could remain liquid. Thus, they wanted to search through the *Kepler* data to find evidence specifically for "Earth-size planets orbiting far enough from Sun-like stars to receive a similar intensity of light energy as Earth," the authors explained.

First, they narrowed their search in the *Kepler* data to 42,557 stars of spectral classes G (yellow) and K (orange), with surface temperatures of 4,100 K to 6,100 K bracketing the Sun's 5,770 K, and masses ranging from 0.6 to 1.1 times the Sun's. Then, with the aid of custom-built software called TERRA, they further looked for evidence of Earth-size planets with orbital periods longer than 50 days. They also quantified the fraction of planets that might have been missed by their census, either because the planes of their orbits were tilted so the planets could not transit the host star as seen from Earth, or those that the TERRA software itself could have missed.

Shedding (the right amount of) light

The intensity of light energy bathing a planet depends on both the star's luminosity and its distance from the planet. So the three astronomers then secured spectra for all 62 host

stars that hosted planets with orbital periods longer than 100 days to precisely determine their luminosity. They ultimately found that some 11 percent (plus or minus 4 percent) of Sun-like stars have a planet 1 to 2 times the size of Earth that receives 1 to 4 times as much sunlight as Earth.

They did not identify any Earth-like planet with TERRA with an orbital period of 200 to 400 days, but they attribute that primarily to the shortness of the *Kepler* survey before the loss of the spacecraft's stabilizing reaction wheel in May 2013, and the difficulty of observing such long-period planets. However, extrapolation from *Kepler* data of



Field of view of the *Kepler* space telescope, located in the constellation Cygnus, just above the plane of the Milky Way Galaxy. Credit: NASA

star systems with shorter-period orbits strongly suggests that nearly 6 percent of Sun-like stars have an Earth-size planet in an Earth-like orbit of 200 to 400 days. "Naturally, such an extrapolation carries less weight than a direct measurement," the authors note in their paper published in *Proceedings of the National Academy of Sciences*, but it "seems unlikely to be unrealistic by more than a factor of 2."

Even planets with shorter orbital periods could also be in the habitable zone, the authors note, for example, around stars of very different spectral types, such as early M dwarfs (small, cool red stars). "Thus, Earth-size planets appear to be common in the HZs [habitable zones] of a range of stellar types," the authors observe.

Upshot: The authors calculated that some 26 percent of more-or-less Sun-like stars have a planet 1 to 2 times the size of Earth, with an orbital period of 5 to 100 days. About 11 percent of Sun-like stars have an Earth-size planet that receives 1 to 4 times Earth levels of stellar energy.

Kepler observed a portion of sky 120 times larger than the full Moon—equivalent to 1/400 of the celestial sphere. The statistics from the *Kepler* region led the authors to make a bold and exciting prediction: "If one were to adopt a 22% occurrence rate of Earth-size planets in habitable zones of Sun-like stars, then the nearest such planet is expected to orbit a star that is less than 12 light-years from Earth and can be seen by the unaided eye." —Trudy E. Bell, M.A.

Further reading: The PNAS paper "Prevalence of Earth-size planets orbiting Sun-like stars" is at <http://www.pnas.org/content/110/48/19273.full>. For more details about the role of the NERSC supercomputer in the computations, see also the NERSC press release "Are Earths Rare? Perhaps Not" at <http://cs.lbl.gov/news-media/news/2014/are-earths-rare-perhaps-not/>.

The University of California High-Performance AstroComputing Center (UC-HIPACC), based at the University of California, Santa Cruz, is a consortium of nine University of California campuses and three affiliated Department of Energy laboratories (Lawrence Berkeley Lab, Lawrence Livermore Lab, and Los Alamos National Lab). UC-HIPACC fosters collaborations among researchers at the various sites by offering travel and other grants, co-sponsoring conferences, and drawing attention to the world-class resources for computational astronomy within the University of California system. More information appears at <http://hipacc.ucsc.edu>