

# EXTRASOLAR PLANETS: THE SAGA CONTINUES

An occasional account of our  
ongoing discoveries of planets  
beyond the solar system.

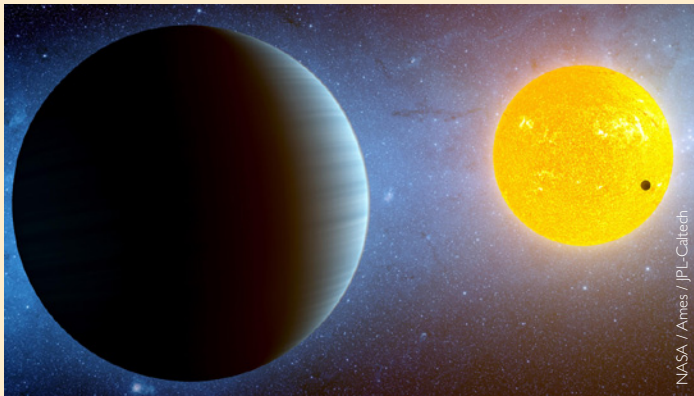
by **Paul Deans**



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Courtesy Astronomical Society of the Pacific

An artist's rendition of the Kepler-35  
planetary system, in which a Saturn-size  
planet orbits a pair of stars every 131 days,  
while the stellar pair orbits each other every  
21 days. Courtesy NASA, Lynette Cook.





**“P**lanet Population is Plentiful,” says the European Southern Observatory in a press release from the January 2012 meeting of the American Astronomical Society (AAS) in Austin, Texas. “A Wealth of Habitable Planets in the Milky Way,” proclaims one more release, this one from the Niels Bohr Institute. “Milky Way Contains at Least 100 Billion Planets,” says another press page from the Space Telescope Science Institute.

Amazing. In less than two decades, we have gone from extraterrestrial planets as the stuff of science fiction to an overwhelming abundance of extrasolar worlds.

Consider. Until 1998 and the first detection of an exoplanet (circling [Gamma Cephei](#)), there was no proof that other worlds existed. For all we knew, our solar system was a unique oddball. Of course, the assumption of our uniqueness, when it dealt with our place in the cosmos, has never stood the test of time.

During the decade following that first find, extrasolar planets were discovered on an occasional basis, with press releases trumpeting each one. Now, thanks to NASA’s [Kepler](#) mission, the discovery of distant worlds has turned from a trickle into a torrent. As a consequence of this data flood, other facilities and researchers are often overlooked, and yet they continue to make discoveries or do critical work confirming Kepler’s finds. And Kepler isn’t the only planet finder hard at work.

So every now and then I’ll take press releases and Web items and assemble an article on exoplanets — probably the hottest topic in astronomy these days. I’ll include as many hotlinks as possible, so you can keep tabs on the search as astronomers seek the Holy Grail of extrasolar planets — an Earth-like world in a star’s habitable zone.

If you’d like to try to keep up, I suggest checking the [Extrasolar Planets Catalog](#) on the Extrasolar Planets Encyclopedia website. You can also use the [Exoplanet Data Explorer](#), an interactive table and plotter for exploring and displaying data from the Exoplanet Orbit Database maintained by the California and Carnegie Planet Search group.

And if you’d like to get involved in searching for planets, head to the [Planet Hunters](#) website — a collaboration between Yale University and Zooniverse. There you can help find new planets by looking at how the brightness of a star changes over time. Who knows? Maybe you will be the one to find that elusive world some are calling Earth II.

— P. D.

## Milky Way Contains at least 100 Billion Planets

Our Milky Way galaxy contains a minimum of 100 billion planets according to a detailed statistical study based on the detection of three extrasolar planets by an observational technique called microlensing.

Kailash Sahu, of the Space Telescope Science Institute in Baltimore, Md., is part of an international team reporting that our galaxy contains a minimum of one planet for every star on average. This means that there is likely to be a minimum of 1,500 planets within just 50 light-years of Earth.

The results are based on observations taken over six years by the PLANET (Probing Lensing Anomalies NETwork) collaboration, which Sahu co-founded in 1995. The study concludes that there are far more Earth-sized planets than bloated Jupiter-sized worlds. This is based on calibrating a planetary mass function that shows the number of planets increases for lower mass worlds. A rough estimate from this survey would point to the existence of more than 10 billion terrestrial planets across our galaxy.

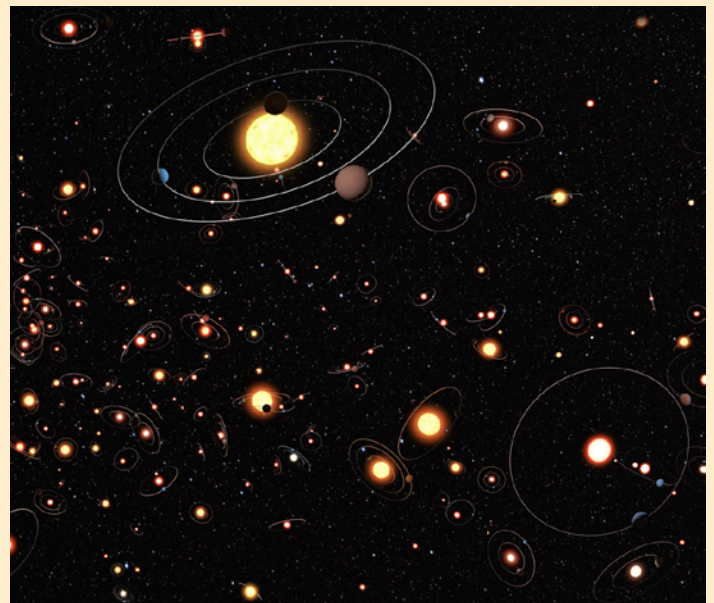
The results were published in the January 12, 2012, issue of the British science journal *Nature*.

The team’s conclusions are gleaned from a planet search technique called microlensing. The technique takes advantage of the random motions of stars, which are generally too small to be noticed. If one star passes precisely in front of another star, the gravity of the foreground star bends the light from the background star.

This means that the foreground star acts like a giant lens amplifying the light from the background star. A planetary companion around the foreground star can produce additional brightening of the background star. This additional brightening reveals the planet, which is otherwise too faint to be seen by telescopes.

The higher the mass of the “lensing” star, the longer is the duration of the microlensing event. Typical microlensing events due to a star last about a month. But the extra brightening due to a planet typically lasts a few hours to a couple of days.

Using the microlensing technique, astronomers can determine a planet’s mass. This method, however, does not reveal any clues



This artist’s illustration gives an impression of how common planets are around the stars in the Milky Way. The planets, their orbits, and their host stars are all vastly magnified compared to their real separations.

about the world's composition.

Unlike other prominent planet-detection techniques, which measure the silhouettes of planets passing in front of their stars (transit) or measure the wobble of a star due to the gravitational tug of a planet (radial velocity and astrometry), the gravitational-lensing technique is unbiased in the selection of the host star.

The other techniques work best for finding planets close to their stars with short orbital periods. But microlensing can detect a planet that is as far from its star as Saturn is from our Sun, or as close as Mercury is to our Sun. The technique is also sensitive to detecting planets as small as Mercury.

Wide-field survey campaigns such as OGLE (Optical Gravitational Lensing Experiment) and MOA (Microlensing Observations in Astrophysics) cover millions of stars every clear night in order to identify and alert stellar microlensing events as early as possible. Follow-up collaborations, such as PLANET, monitor selected candidates more frequently, 24 hours a day, using a round-the-world network of telescopes.

Of the approximately 40 microlensing events closely monitored, three showed evidence for exoplanets. Using a statistical analysis, the team found that one in six stars hosts a Jupiter-mass planet. What's more, half of the stars have Neptune-mass planets, and two-thirds of the stars have Earth-mass planets. Therefore, low-mass planets are more abundant than their massive counterparts.

"This means, statistically, every star in the galaxy should have at least one planet, and probably more," said Sahu.

"Results from the three main techniques of planet detection are rapidly converging to a common result: Not only are planets common in the galaxy, but there are more small planets than large ones," said Stephen Kane, a co-author from NASA's Exoplanet Science Institute at the California Institute of Technology, Pasadena, Calif. "This is encouraging news for investigations into habitable planets."

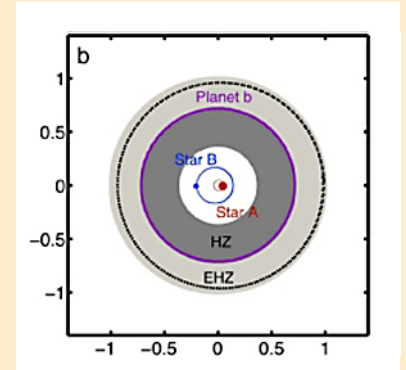
These results are independent from a gravitational-lens survey led by Takahiro Sumi of Osaka University in Japan, which estimates there are hundreds of billions of planets with orbits larger than Saturn's orbit, or are free-floating throughout the galaxy.

### Scientists Searching for Earth-type Planets Should Consider Two-Star System

A group of astrophysicists from The University of Texas at Arlington plans to expand the discussion about a newly discovered planet orbiting two stars by presenting a study suggesting where an Earth-type planet could exist in the system.

The Kepler-16 System made headlines in September [2011] when researchers at NASA's Kepler space telescope mission revealed the discovery of Kepler-16b, a cold, gaseous planet that orbits two stars like Star Wars' fictional Tatooine.

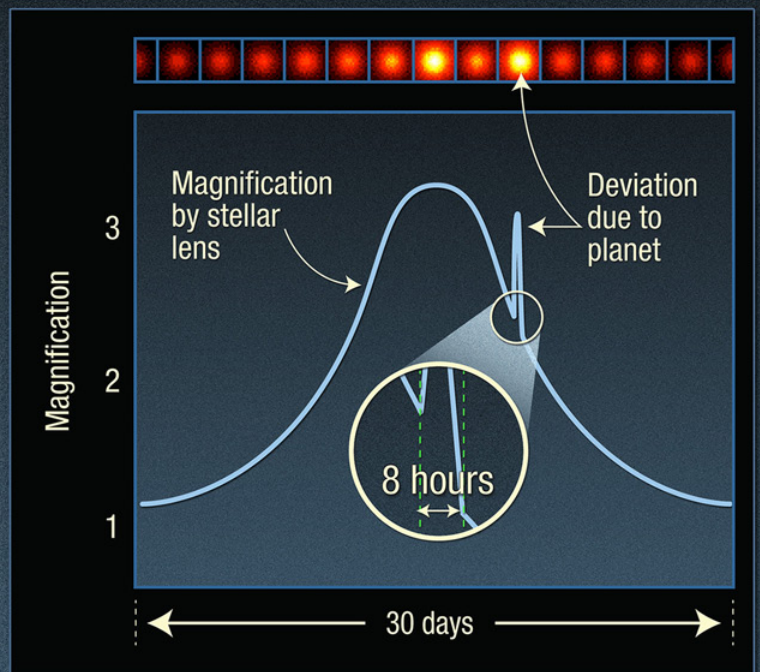
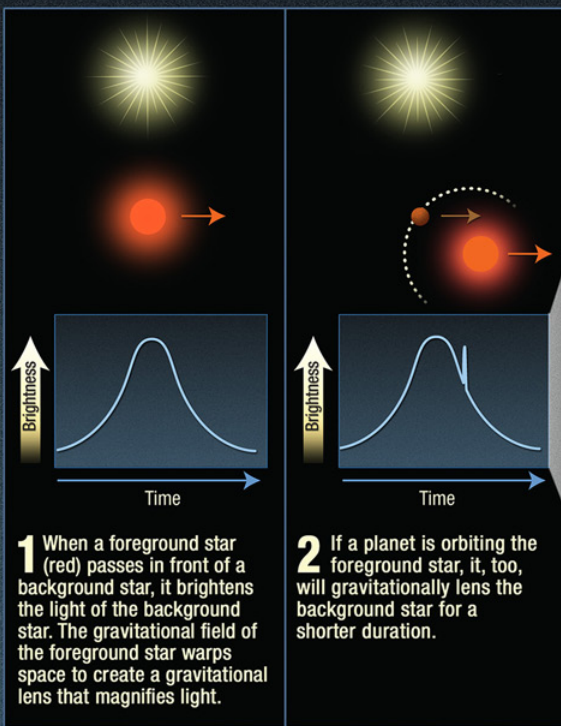
The UT Arlington team, using data from the Kepler and previous research, have concluded that an Earth-type planet could exist in the system's "habitable zone" as an exomoon orbiting Kepler-16b. They also think an "extended habitable zone" exists outside the orbit of the gaseous planet, under certain conditions. To host life in that zone, a terrestrial planet orbiting the two stars



University of Texas at Arlington

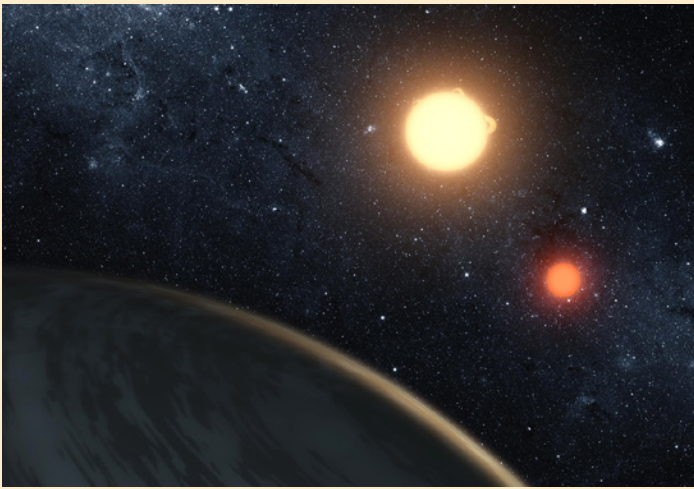
An illustration of the habitable zone (HZ) and extended habitable zone (EHZ) in the Kepler-16 System. The axes are given in Astronomical Units.

## Extrasolar planet detected by gravitational microlensing



NASA / ESA / A. Feild (STScI)





NASA / JPL-Caltech / T.Pyle

**This artist's concept illustrates Kepler-16b, the first planet known to definitively orbit two stars —called a circumbinary planet. The two orbiting stars regularly eclipse each other, as seen from our point of view on Earth. The fact that the orbits of the stars and the planet align within a degree of each other indicates that the planet formed within the same circumbinary disk that the stars formed within, rather than being captured later by the two stars.**

would need to have high levels of greenhouse gases in its atmosphere such as carbon monoxide or methane, they said.

Billy Quarles, a doctoral student in the UT Arlington College of Science, presented the findings at the annual meeting of the American Astronomical Society on January 9 in Austin, Texas.

"This is an assessment of the possibilities," said UT Arlington Department of Physics professor Zdzislaw Musielak. "We're telling them where a planet has to be in the system to be habitable. We're hoping they will look there."

The Kepler Mission is a space telescope launched by NASA in 2009 that measures light from 150,000 stars. Scientists working with Kepler data look for changes in stellar brightness that suggest a transit, or a planet passing in front of a star. They use measurements of the star's luminosity to determine whether the planet is in a "habitable zone," an area where the planet would be orbitally stable and where conditions hospitable to the formation and sustenance of life could exist.

The UT Arlington team based their conclusions about an "extended habitable zone" outside the orbit of Kepler-16b on work by scientists such as NASA's Michael A. Mischna. That research says life could be found outside the traditional habitable zone, but it requires a more extreme planetary atmosphere, one in which chemicals in the atmosphere create a strong back-warming effect, Quarles said.

"There is less light from the star, so the planet itself has to maintain more heat," he said.

## Discovery Establishes New Class of Planetary Systems

Using data from NASA's Kepler Mission, astronomers announced the discovery of two new transiting "circumbinary" planet systems — planets that orbit two stars. This work establishes that such "two sun" planets are not rare exceptions, but are in fact common with many millions existing in our galaxy. The work was presented by Dr. William Welsh of San Diego State University at the American Astronomical Society meeting in Austin, Texas, on behalf of the Kepler Science Team.

The two new planets, named Kepler-34 b and Kepler-35 b, are

both gaseous Saturn-size planets. Kepler-34 b orbits its two Sun-like stars every 289 days, and the stars themselves orbit and eclipse each other every 28 days. The eclipses allow a very precise determination of the stars' sizes. Kepler-35 b revolves about a pair of smaller stars (80% and 89% of the Sun's mass) every 131 days, and the stars orbit and eclipse one another every 21 days (see the illustration on [page 24](#)). Both systems reside in the constellation Cygnus, with Kepler-34 at 4,900 light-years from Earth, and Kepler-35 at 5,400 light-years, making these among the most distant planets discovered.

While long anticipated in both science and science fiction, the existence of a circumbinary planet orbiting a pair of normal stars was not definitively established until the discovery of Kepler-16 b, announced by the Kepler Team last September. Like Kepler-16 b, these new planets also transit (eclipse) their host stars, making their existence unambiguous. When only Kepler-16 b was known, many questions remained about the nature of circumbinary planets — what kinds of orbits, masses, radii, temperatures, etc., could they have? And most of all, was Kepler-16 b just a fluke?

With the discovery of Kepler-34 b and 35 b, astronomers can now answer many of those questions and begin to study an entirely new class of planets. "It was once believed that the environment around a pair of stars would be too chaotic for a circumbinary planet to form, but now that we have confirmed three such planets, we know that it is possible, if not probable, that there are at least millions in the galaxy," said Welsh. Dr. Laurance Doyle of the SETI Institute, further stated, "With this paper, the new field of comparative circumbinary planetology is now established."

The discovery was made possible by the three unique capabilities of the Kepler space telescope: its ultra-high precision, its ability to simultaneously observe roughly 160,000 stars, and its long-duration near-continuous measurements of the brightness of stars. Additional work using ground-based telescopes provided velocity measurements of the stars needed to confirm that these candidates are really planets. "The search is on for more circumbinary planets," said co-author Dr. Joshua Carter of the Harvard-Smithsonian Center for Astrophysics, "and we hope to use Kepler for years to come."

A circumbinary planet has two suns, not just one. The distances between the planet and stars are continually changing due to their orbital motion, so the amount of sunlight the planet receives varies dramatically.

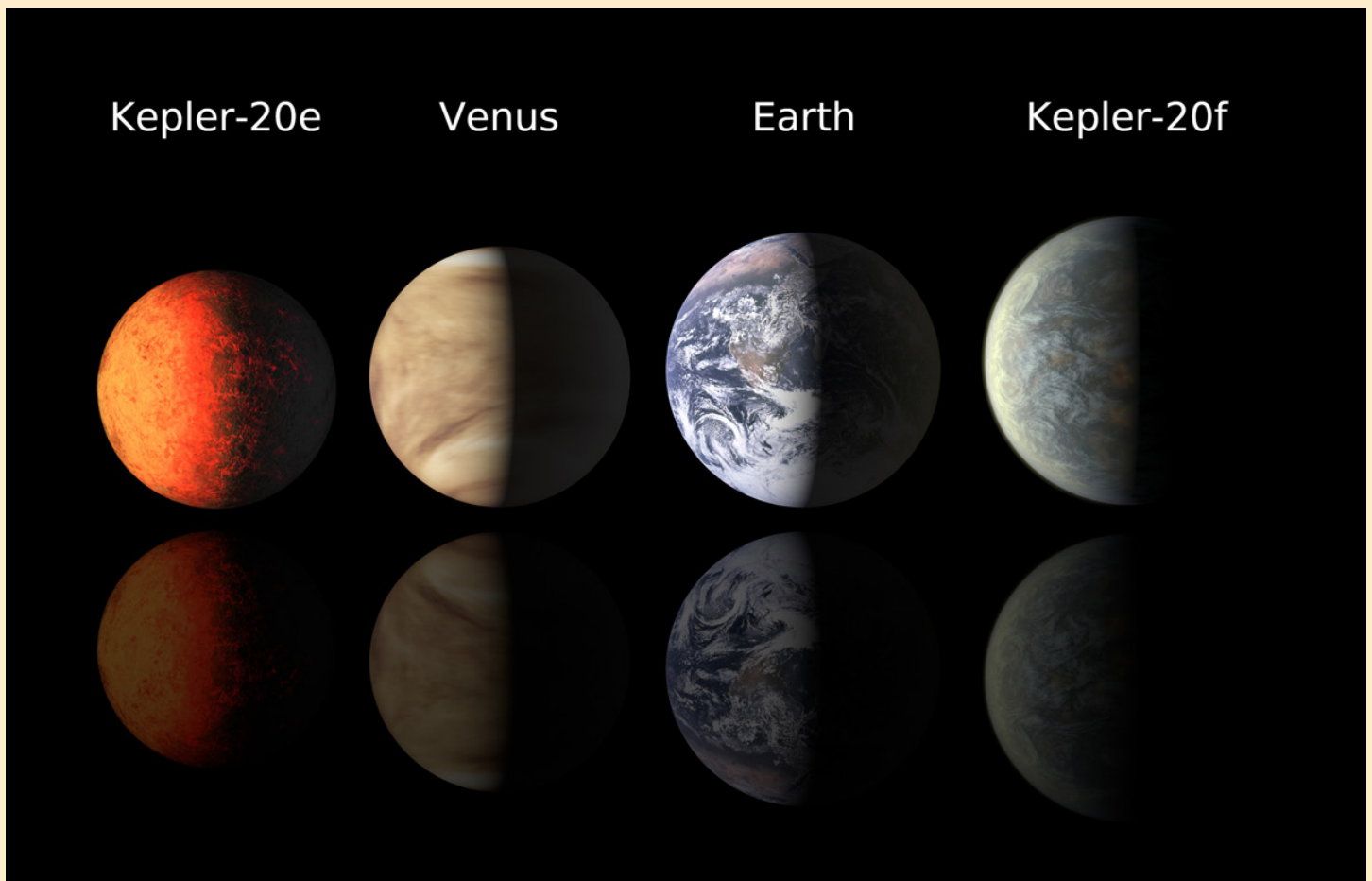
"These planets can have really crazy climates that no other type of planet could have," said Dr. Jerome Orosz, a co-author from San Diego State University. "It would be like cycling through all four seasons many times per year, with huge temperature changes." Welsh adds, "The effects of these climate swings on the atmospheric dynamics, and ultimately on the evolution of life on habitable circumbinary planets, is a fascinating topic that we are just beginning to explore."

## First Earth-size Planets Found

Astronomers using NASA's Kepler mission have detected two Earth-sized planets orbiting a distant star. This discovery marks a milestone in the hunt for alien worlds, since it brings scientists one step closer to their ultimate goal of finding a twin Earth.

"The goal of Kepler is to find Earth-sized planets in the habitable zone. Proving the existence of Earth-sized exoplanets is a major step toward achieving that goal," said Francois Fressin of the Harvard-Smithsonian Center for Astrophysics (CfA).

The two planets, dubbed Kepler-20e and 20f, are the smallest planets found to date. They have diameters of 6,900 miles and 8,200 miles — equivalent to 0.87 times Earth (slightly smaller than Venus)



The first two Earth-sized exoplanets found by Kepler are shown here in comparison to Earth and Venus.

and 1.03 times Earth. These worlds are expected to have rocky compositions, so their masses should be less than 1.7 and 3 times Earth's.

Both worlds circle Kepler-20: a G-type star slightly cooler than the Sun and located 950 light-years from Earth. Kepler-20e orbits every 6.1 days at a distance of 4.7 million miles. Kepler-20f orbits every 19.6 days at a distance of 10.3 million miles. Due to their tight orbits, they are heated to temperatures of 1,400 degrees Fahrenheit and 800 degrees F.

In addition to the two Earth-sized worlds, the Kepler-20 system contains three larger planets. All five have orbits closer than Mercury in our solar system.

They also show an unexpected arrangement. In our solar system small, rocky worlds orbit close to the Sun and large, gas giant worlds orbit farther out. In contrast, the planets of Kepler-20 are organized in alternating size: big, little, big, little, big.

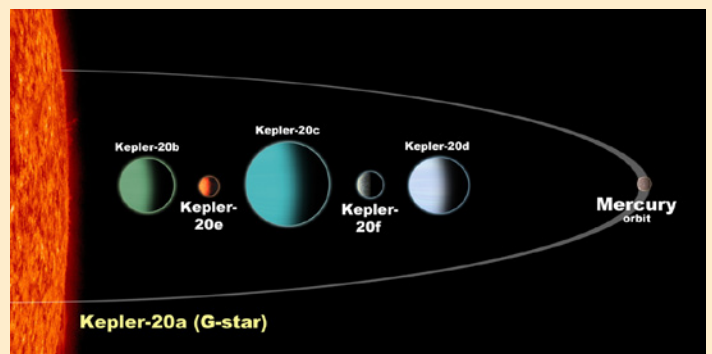
"We were surprised to find this system of flip-flopping planets," said co-author David Charbonneau of the CfA. "It's very different than our solar system."

The three largest planets are designated Kepler-20b, 20c, and 20d. They have diameters of 15,000, 24,600, and 22,000 miles and orbit once every 3.7, 10.9, and 77.6 days, respectively. Kepler-20b has 8.7 times the mass of Earth; Kepler-20c has 16.1 times Earth's mass. Kepler-20d weighs less than 20 times Earth.

The planets of Kepler-20 could not have formed in their current locations. Instead, they must have formed farther from their star and then migrated inward, probably through interactions with the disk of material from which they all formed. This allowed the

worlds to maintain their regular spacing despite alternating sizes.

"These new planets are significantly smaller than any planet found up till now orbiting a Sun-like star," added Fressin. [\[RETURN\]](#)



The Kepler-20 planetary system contains five planets that alternate in size: large, small, large, small, large. All five orbit their star closer than the planet Mercury in our solar system. Although too hot to be hospitable to life, Kepler-20e and 20f are the first Earth-sized planets to be discovered orbiting a distant star. In this artist's rendering, the planetary sizes are to scale but their orbital spacing is not.

As the editor of Mercury, PAUL DEANS receives numerous press releases about extrasolar planets. He hopes astronomers find evidence of alien life on another world during his lifetime.