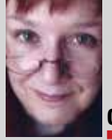


COSMIC BACKGROUND BY MARCIA BARTUSIAK

Like This World of Ours

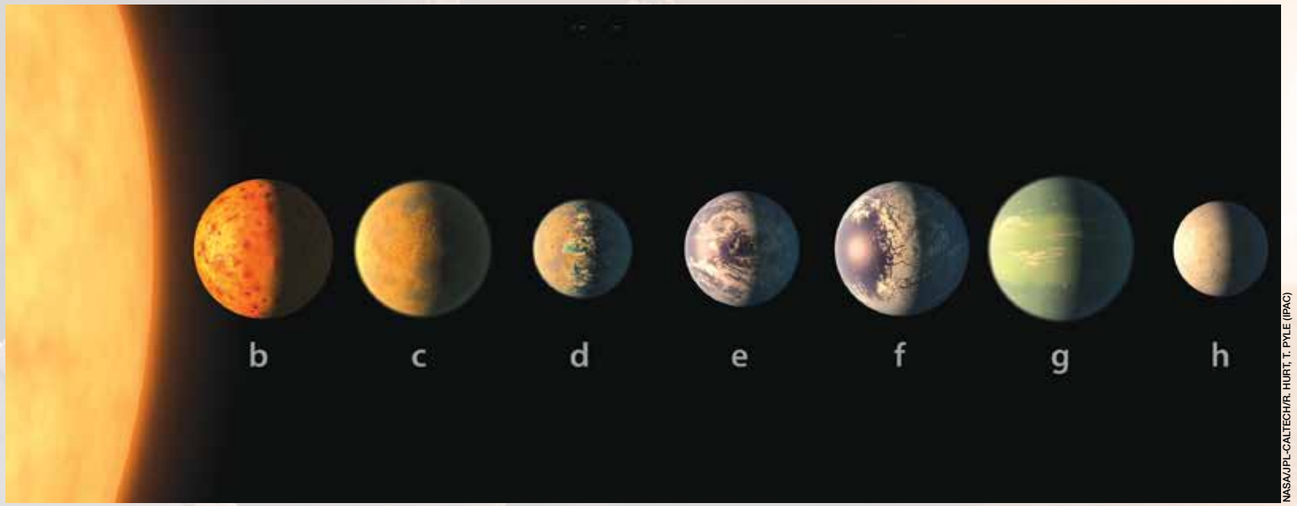
Validation of long-time speculation

On February 22, 2017, an international team of astronomers made the thrilling revelation that after examining a collection of data, gathered by both NASA's Spitzer Space Telescope and an array of telescopes around the world, they had found at least seven exoplanets—all roughly the size of the Earth—closely circling a red, Jupiter-sized star known as TRAPPIST-1. The star had been named after the TRAnsiting Planets and PlanetesImals Small Telescope network in Chile and Morocco, which first encountered this extrasolar system. At least three of TRAPPIST-1's rocky planets are likely to harbor liquid water, but so could all seven.

More exciting is that these terrestrial-like worlds are located a relatively scant 39 light-years away in the direction of the Aquarius constellation. In cosmic terms, that's right next door. Such proximity will allow astronomers to achieve one of their fondest dreams: eventually using current and future telescopes to study the planets' atmospheres in search of gases conducive to life, such as oxygen, ozone, and carbon dioxide.

According to the Extrasolar Planets Encyclopedia, the number of extrasolar planets so far revealed in our galaxy totals over 3,600. The TRAPPIST system is only the latest find in the burgeoning field of exoplanetary astronomy. Although this is a rather new scientific field, speculation that planetary systems circle other stars started in ancient times. In the fourth century BCE, the Greek philosopher Epicurus, in a letter to his student Herodotus, surmised that there are "infinite worlds both like and unlike this world of ours." As he believed in an infinite number of atoms careening through the cosmos, it only seemed logical that they'd ultimately construct limitless other worlds.

The noted eighteenth-century astronomer William Herschel, too, conjectured that every star might be accompanied by its own band of planets but figured they could "never be perceived by us on account of the faintness of light." He knew that a planet, visible only by reflected light, would be lost in the glare of its sun when viewed from afar.



NASA/JPL-CALTECH/R. HURT, T. PYLE (IPAC)

An artist's concept of TRAPPIST-1's seven planets based on data about their diameter, mass and distance from the host star. All are Earth-sized, terrestrial, and tidally locked (i.e., the same face of each planet is always pointed at the star). Planets b and c receive the most light and are the warmest. Planets e, f, and g orbit in the habitable zone, where liquid water is most likely to be detected. However, any of the planets could harbor liquid water, depending on their compositions. Planet d shows a narrow band of water near the terminator, the divide between a hot, dry day and an ice-covered night side. Planets e and f are covered in water with progressively larger ice caps on their night side. Planet g is shown with a Neptune-like atmosphere, although it is still rocky. Planet h, the farthest from the star, would be the coldest. It is portrayed here as an icy world, but the least is known about it.

But astronomers eventually realized that a planet might be detected by its gravitational pull on a star, causing the star to systematically wobble like an unbalanced tire as it moves through the galaxy. Starting in 1938, Peter van de Kamp at Swarthmore College spent decades regularly photographing Barnard's star, a faint red dwarf star located six light-years away that shifts its position in the celestial sky by the width of the Moon every 180 years, faster than any other star. By the 1960s, van de Kamp got worldwide attention when he announced that he did detect a wobble, which seemed to indicate that at least one planet was tagging along in the star's journey. But by 1973, once Allegheny Observatory astronomer George Gatewood and Heinrich Eichhorn of the University of Florida failed to confirm the Barnard-star finding with their own, more sensitive photographic survey, van de Kamp's celebrated claim of detecting the first extrasolar planet disappeared from the history books.

The wobble technique lived on, however, in another fashion. Astronomers began focusing on how a stellar wobble would affect the star's light. When a star is tugged radially *toward* the Earth by a planetary companion, the stellar light waves get compressed—that is, made shorter and thus shifted toward the blue end of the electromagnetic spectrum. When pulled *away* by a gravitational tug, the waves are extended and shifted the other way, toward the red end of the spectrum. Over time, these periodic changes in the star's light can become discernible, revealing how fast the star is moving back and forth due to planetary tugs.

In 1979, University of British Columbia astronomers Bruce Campbell and Gordon Walker pioneered a way to detect velocity changes as small as a dozen meters a second, sensitive enough for extrasolar planet hunting to begin in earnest. Constantly improving their equipment, planet hunters were even more encouraged in 1983 and 1984 by two momentous events: the Infrared Astronomical Satellite (IRAS) began seeing circumstellar material surrounding several stars in our galaxy; and optical astronomers, taking a special image of the dwarf star Beta Pictoris, revealed an edge-on disk that extends from the star for some 37 billion miles. It was the first striking evidence of planetary systems in the making, suggesting that such systems might be common after all.

The first indication of an actual planet orbiting another star arrived unexpectedly and within an unusual environment. In 1991, radio astronomers Alex Wolszczan and Dale Frail, while searching for millisecond pulsars at the Arecibo observatory in Puerto Rico, saw systematic variations in the beeping of pulsar B1257+12, which suggested that three bodies were orbiting the neutron star. Rotating extremely fast, millisecond pulsars are spun up by accreting matter from a stellar companion. So, this system, reported Wolszczan and Frail, "probably consists of 'second generation' planets created at or after the end of the pulsar's binary history."

The principal goal for extrasolar planet hunters at that time was finding evidence for "first generation" planets around stars like our Sun. That long-anticipated event at last occurred in 1994 when Geneva Observatory astronomers Michel Mayor and Didier Queloz, working from the Haute-Provence observatory in southern France, discerned the presence of an object similar to Jupiter orbiting 51 Pegasi, a sun-like star 45 light-years distant in the constellation Pegasus. They first revealed their discovery at a conference in Florence, Italy, and their fellow astronomers declared it a "spectacular detection." Unlike our own solar system, this extrasolar planet is located a mere four-and-a-half million miles from its star (far closer in than Mercury is to our Sun) and completes one orbit every four days. Planet hunters had assumed it would take years of collecting data before detecting the subtle and gradual stellar wobbles caused by a planet orbiting its parent star, but the small orbit of 51 Pegasi b enabled them to spot its variations quickly.

Other discoveries followed swiftly. Geoffrey Marcy and R. Paul Butler, then both at San Francisco State University and friendly competitors of the Geneva observers, had been gathering radial velocity data at Lick Observatory since 1987. Searching through their records, they found evidence for a planet similar to 51 Peg b, a body at least seven times the mass of Jupiter closely circling within 40 million miles of the star 70 Virginis.

These finds challenged theorists, who had not imagined giant planets with eccentric orbits so close to their sun. These unusual planets, though, were quickly overshadowed by a simultaneous discovery by Marcy and Butler—a large planet orbiting 47 Ursae Majoris at a more distant 200 million miles. This companion of 47 Ursae Majoris thus gained special distinction for being more "reminiscent of solar system planets." And by 1999, Butler, Marcy, and several colleagues found the first multiple planetary system, a trio of planets circling the star Upsilon Andromedae.

The floodgates were opened, eventually leading to a few thousand exoplanets being found. While at first only the biggest exoplanets were revealed (as it was easier to detect them), improved technologies and additional planet-hunting methods enabled the discovery of smaller exoplanets, including Earth-like planets. Space-based missions, such as the Kepler space telescope, were especially productive. "We've gone from the early days of thinking maybe there are five or ten other planets out there, to realizing almost every star next to us might have a planet," says astronomer Jennifer Burt at MIT's Kavli Institute for Astrophysics and Space Research. Indeed, one team of astronomers in 2012 estimated that there might be one or more planets orbiting each and every Milky Way star, a potential of at least 200 billion. "We conclude," wrote the astronomers in their *Nature* report, "that stars are orbited by planets as a rule, rather than the exception."

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