Searching for Other Worlds

A planetary odyssey

By RON COWEN

Forget speculation. It's no longer a matter for debate. As of last month, astronomers have proven they're out there—planets orbiting ordinary stars within a stone's throw of our solar system.

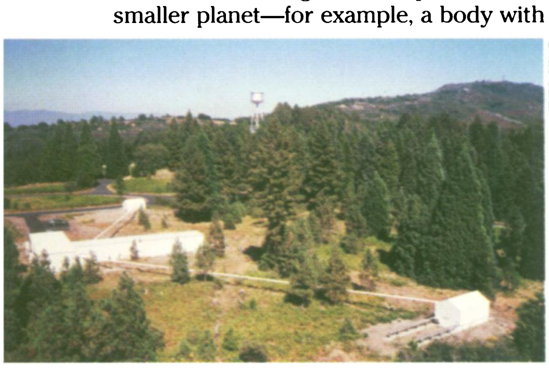
Two startling announcements in early October brought the notion of extrasolar planets out of the shadows and into the spotlight (SN: 10/21/95, p.260). The unexpected news also provided a shot in the arm for a NASA-appointed panel that 2 weeks ago gave Administrator Daniel Goldin its recommendations on strategies for searching out planets over the next 10 to 20 years.

Ironically, neither finding required state-of-the-art detectors like those the NASA panel evaluated in its report. But many astronomers believe the discoveries represent oddballs, planetlike bodies that were easily found precisely because of their unusual characteristics.

Consider the planet with a mass similar to Jupiter's that a Swiss team found around the sunlike star 51 Pegasi. This planet ventures so close to 51 Pegasi—one-fifth the distance between Mercury and the sun—that it passes inside the star's hot outer atmosphere, or corona.

At the other end of the spectrum, U.S. researchers discovered a veritable heavyweight—either a big planet or a small failed star known as a brown dwarf—as massive as 20 Jupiters, circling the nearby star GL229 at a distance beyond that of Pluto's orbit about the sun.

To obtain images and spectra of a smaller planet—for example, a body with the mass of Uranus—circling a nearby star at roughly Jupiter's distance from the sun, astronomers will need technology that's only now under development. And to find a planet similar to Earth that lies neither too close to nor too far away from its parent star to support life will probably require an infrared observatory in space.


Shao et al.

Combining light from two 0.4-meter telescopes located 100 meters apart forms a single infrared interferometer at Mount Palomar Observatory.

Most proposed surveys focus on the nearest 1,000 stars, those within about 42 light-years of the solar system. Planet-hunting strategies run the gamut from launching an array of detectors into an orbit as distant as Jupiter's to using ground-based detectors already employed in the search for galactic dark matter. Despite their variety, nearly all strategies fall into one of two categories, notes David C. Black, director of the Lunar and Planetary Institute in Houston.

Indirect methods focus exclusively on the parent star. Telltale wobbles in its motion betray the gravitational tug of an unseen planet, and periodic dimming of its light could signify a planet crossing in front of it.

In contrast, direct methods aim to produce images and spectra of the planet itself. Such approaches must block out light from the parent star, Black notes; otherwise, the glare will drown out the faint glow from the planet.

Among indirect methods, astrometry and spectroscopy record different facets of the motion of stars, while photometry records changes in brightness. A fourth technique, which relies on the phenomenon of gravitational lensing, holds the promise of detecting Earth-mass planets but does not enable observers to study them.

As a planet circles its parent star, moving from one side to another, it pulls the parent to and fro, creating a wobble in the star's motion. Astrometry, the precise tracking of a star's movement across the sky, detects the wobble—if it's large enough. This method works best if the planet lies relatively far away from the star it orbits. The larger the planet's orbit, the greater the excursion the star must make as it revolves around the center of mass of the two bodies.

The spectroscopic method, on the other hand, detects the star's back-and-forth motion along the line of sight to Earth. As the star moves toward Earth, the light it emits appears shifted to a bluer, or shorter, wavelength; as it moves away, its light gets shifted to redder, or longer, wavelengths.

Using spectroscopy to analyze shifts in wavelength over time, astronomers can look for periodic motion suggestive of an unseen planet. And unlike astrometry, the spectroscopic method does not depend on how far from Earth the star resides—if it's bright enough. Distant stars appear to have a smaller wobble than nearby stars as they move across the sky, but their back-and-forth motion remains the same.

Spectroscopy has a second distinguishing characteristic: It excels when the planet lies close to the star and has a shorter period. A nearby planet imparts a larger back-and-forth velocity to the star, which shows up as a larger shift in wavelength.

A case in point is last month's discovery of a planet around 51 Pegasi. The researchers made their discovery with relative ease because of the planet's extreme proximity to its parent. Moreover, the planet's short period—it takes only 4 days to circle the star—enabled astronomers at the Lick Observatory on Mount Hamilton, Calif., to confirm the spectroscopic finding in just 4 days of observations.

According to Michael Shao of NASA's Jet Propulsion Laboratory in Pasadena, Calif., both astrometry and spectroscopy have the same nemesis: starspots. These blemishes, akin to sunspots, tend to have a lower temperature than surrounding regions. When a starspot rotates into view, it can confound spectroscopic measurements. The cooler, lower-energy emission from a starspot can mimic a shift in wavelength.

Starspots also pose a problem, though a far lesser one, for astronomers who track the motion of the star across the sky. Such a blemish can give the star a lopsided appearance, making it seem as though the star has wobbled when it hasn't.

The bottom line, notes Shao, is that both of these indirect methods of detection lack the sensitivity to detect Earth-mass planets around nearby stars similar to the sun.

At Palomar Observatory near Escondido, Calif., Shao and his colleagues recently paired two 0.4-meter infrared telescopes, located 100 meters apart, to serve as a high-resolution astrometer. The telescopes, which together form an infrared interferometer, combine their images, acting as a single large telescope. This enables Shao's team to track more precisely the motion of stars across the sky.

Shao notes that after the interferometer has detected a wobble in a star's motion, it can attempt to image the planet responsible. Because the planet orbiting 51 Pegasi emits a significant amount of heat, the infrared instrument may have a chance of imaging it, he says.

The setup at Palomar will begin searching for planets around 60 nearby stars in January. According to Shao, the device can detect planets at least as massive as Uranus orbiting at least Jupiter's distance from Earth. The interferometer will serve as a test bed for a much larger device, which astronomers hope to install at the W.M. Keck Observatory atop Hawaii's Mauna Kea at the turn of the century.

Some astronomers are attempting to image planets directly from the ground. One method attacks the most serious problem encountered in trying to discern faint objects—our planet's turbulent atmosphere, which blurs telescopic images. Using a deformable telescope mirror controlled by computer, researchers can compensate for the blurring by generating an optical aberration exactly opposite that caused by the atmosphere. Flexing mirrors now in use refocus the blurry image up to 100 times a second, faster than the rate at which Earth's atmosphere fluctuates.

Several telescopes, including the European Southern Observatory's New Technology Telescope in La Silla, Chile, incorporate adaptive optics systems of this sort. Roger Angel of the Steward Observatory in Tucson, Ariz., plans to install a state-of-the-art system on the 6.5-meter Monolithic Mirror Telescope now under construction at the observatory. This design will feature a mirror that flexes about 2,000 times a second, an improvement deemed necessary for hunting planets.

In the Jan. 20 SCIENCE, Alan P. Boss of the Carnegie Institution of Washington, D.C., concluded that giant, Jupiter-mass planets are most likely to form within a narrow range of distances from their parent star, similar to Jupiter's distance from the sun. If his calculations hold true, then the newest generation of large telescopes outfitted with adaptive optics will have the ability to image giant planets as much as 25 light-years from the solar system, Steven M. Stahl and David G. Sandler of ThermoTrex Corp. in San Diego report in the Dec. 1, ASTROPHYSICAL JOURNAL LETTERS.

"It has been supposed that a near-perfect space telescope would be required to avoid atmospheric blurring. But by using adaptive optics operating at fundamental performance limits, the new generation of large, ground-based telescopes has the potential to detect planets orbiting nearby stars," Angel declared in the March 17, 1994 NATURE.

Even so, astronomers agree that to detect Earth-mass planets and to analyze their chemical composition, there's still no place like space.

"The possibility for exploration with space telescopes unhampered by atmospheric absorption and blurring is remarkable," says Black. "Planets like Earth would be detectable, and if found, measurements of their chemical and physical characteristics as well as their masses and orbits would be possible."

In part, that's because planets stand out most clearly in the infrared, and water vapor in Earth's atmosphere prevents such wavelengths from ever reaching the ground.

For both imaging and spectroscopy, infrared is the wavelength of choice, notes Black. Whatever faint light planets emit, they radiate more of it in the infrared than in visible light. A sunlike star may shine a billion times more brightly than a planet in visible light, but only a million times more brightly at an infrared wavelength of 10 micrometers.

As for fingerprinting the composition of a planet, says Black, "the infrared has a richness of molecular lines not present almost anywhere else in the electromagnetic spectrum." In particular, molecules associated with life—ozone, water, and carbon dioxide—have clear infrared signatures.

Even when observing from beyond Earth's atmosphere, however, telescopes must contend with spurious infrared radiation from dust, both within our solar system and swaddling planetary systems around other stars. At infrared wavelengths, the total amount of dust in the solar system outshines Earth by a factor of 100.

The European Space Agency's Infrared Space Observatory, launched earlier this month, and NASA's proposed Space Infrared Telescope Facility will provide some help for planet-hunting surveys by mapping the distribution of dust around other stars. Neither telescope, however, can accurately discern such dust unless its distance from the star is more than 10 times the distance between Earth and

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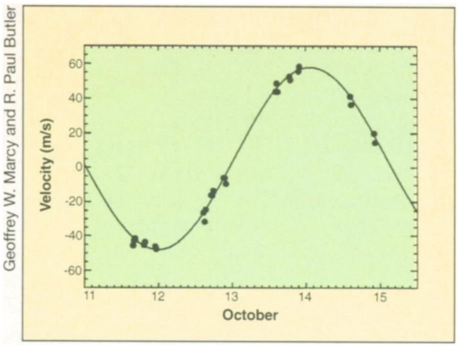

Spectrum of light emitted by the nearby star 51 Pegasi shows periodic back-and-forth motion along the line of sight to Earth that betrays the gravitational tug of an unseen planet.

the sun.

During a servicing mission scheduled for 1997, astronauts will outfit the Hubble Space Telescope with an infrared camera and imaging spectrometer. But Hubble's primary mirror is too small and its optics, even after repair, too imperfect to search for planets beyond the nearest stars, those within 15 light-years of Earth. If Hubble finds a planet, it would appear as a blurry patch of light.

To image a small planet that lies farther from Earth, a detector must somehow blot out the light from the central star. A coronagraph, a black disk set at the prime focus of a telescope, provides one way to accomplish this task. Scientists are thinking about installing such a device on Hubble in 2002, along with an adaptive optics system that should improve its ability to discern faint objects. A balloon-borne telescope outfitted with a coronagraph and adaptive optics may serve as an alternative to this plan.

Such instrumentation pales when compared in scope—and cost—to a proposed 70-meter imaging interferometer in space. In this system, images from the individual telescopes combine in such a way that light from the central star cancels itself out but light from the star's planets is enhanced.

Angel envisions that astronauts would assemble this billion-dollar device at the U.S.-Russian space station and then launch it into an orbit past Jupiter, where dust is much less dense than in the inner solar system.

"We are now clearly embarked upon a journey that will provide within the next decade or so an unambiguous assessment of whether the solar system is a relatively unique phenomenon or whether, as we and Copernicus would suspect, it is a common occurrence in nature," Black comments.

"Either outcome will mark a major step in our efforts to understand the universe in which we live, as well as our place in it." □