ASTRONOMY

Pulsing Star Confirms More Planets in the Universe

The days of disappearing planets seem to be over. Many times in the last century astronomers have reported the first detection of a planet outside our solar system—and then watched dejectedly as others failed to confirm the finding or proved it to be something quite different from a planet, after all. Now further study of a slightly out-of-step stellar clock points to an extrasolar planet that appears to be here to stay.

Actually, the evidence points to several planets. On page 538, Alexander Wolszczan of Penn State University confirms a claim he and Dale Frail of the National Radio Astronomy Observatory made in January 1992: that at least two planetary bodies were orbiting a type of star known as a pulsar (*Science*, 17 January 1992, p. 290). Wolszczan's latest numbers have now convinced his peers these spheres are for real. "There is now, I think, completely irrefutable evidence for at least two planets and probably a whole planetary system," says Fred Rasio of the Institute for Advanced Study in Princeton, who had predicted how Wolszczan might confirm the planets. "It would be difficult to imagine another way the data could be fooling us," agrees Caltech astronomer Stephen Thorsett.

This piece of astronomical detective work had modest beginnings. In 1990, recalls Wolszczan, he was working at the 305-meter radiotelescope at Arecibo, Puerto Rico, when the instrument was closed to outsiders for structural repairs that left it immobile, but still able to survey the sky overhead. This windfall of observing time gave him a few weeks to conduct a search for pulsars, rotating neutron stars so named because they send pulses of radio waves toward Earth with clocklike regularity. For one pulsar that he discovered, located 1500 light-years away in the Virgo constellation, Wolszczan began to closely monitor the times when the faint bursts of radiowaves arrived.

As the data accumulated over 2 years, he noticed something strange about the pulses. Sometimes they came a few milliseconds ear-

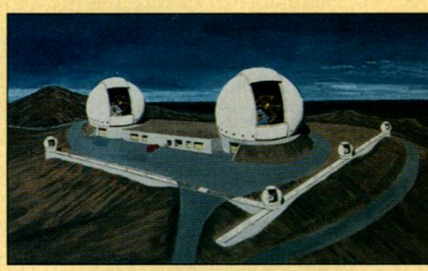
Other Planets, Other Searches

The U.S. space agency abandoned its search for radio signals from "E.T." last year, at Congressional behest, but the agency is still looking for a planet that an alien might call home. They're not planning to look at pulsars, however, even though the first confirmed planetary bodies outside our solar system have been found around these stellar cinders left over from a supernova's blast (see main story). Like most extrasolar planet searchers, the National Aeronautics and Space Administration (NASA) believes nearby sunlike stars are more interesting candidates to study, since their planets have at least a fighting chance of harboring E.T. or a relation; pulsars blast their surrounding neighborhood with fierce radiation thought inhospitable to life.

NASA's multistage program, Astronomical Studies of Extrasolar Planetary Systems or ASEPS, should get underway later this year with powerful ground-based telescopes searching for the presence of Jupiter-sized planets around 100 candidate stars. In the next decade, the program aims to move above the atmosphere with an orbiting instrument to spot planetary bodies, possibly culminating a few decades from now with a lunar observatory to intensively study extrasolar twins of Earth. "We think the techniques [and technology] are now available to really find these objects," says Jurgen Rahe of NASA's Solar System Exploration Division.

Funding, of course, is another matter. NASA would have to ask Congress for billions to fund their most ambitious stages, but agency officials argue that their goal has strong support. "The enthusiasm for this quest, to look for planets around nearby stars and then for life that shares a common bond with us, is one of those things that's almost innate in humans," says Fred Vescelus, program manager for ASEPS.

The initial stage of the quest will begin with help from the 10-meter Keck I and its incomplete twin Keck II, two of the world's most powerful astronomical instruments. ASEPS is wrapping up negotiations to buy one sixth of their total annual observing time and has already allocated $7 million for that effort this year. Even with just one Keck, astronomers can analyze the spectrum of emitted light from a star, looking for shifts in wavelength that indicate the gravitational tug of an orbiting body is affecting the star's velocity. When both scopes come on line, researchers can train them on the same star, combining the gathered light to pinpoint the star's location in space. The technique, known as astrometric interferometry, allows more precise placement of the star than either scope alone. Small, mobile "outrigger" telescopes around Keck I and Keck II will be added to the system later, further improving measurements. Planet searchers use astrometry to indirectly reveal an orbiting companion, as its mass causes a star to "wobble" back and forth slightly in space.



ASEPS/JPL

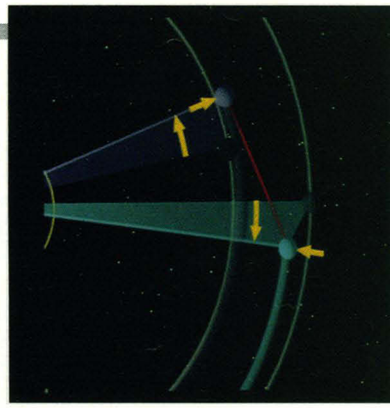
Planet spotters. "Outrigger" telescopes may join the two large Kecks in the planet search.

For ASEPS' second stage, in which the intent is to leave the blurring atmosphere of Earth behind, NASA has been funding studies of four space-based planet searching instruments. The designs range from orbiting interferometers to a satellite that monitors the brightness of stars to spot the eclipsing transits of planets. NASA will request final proposals soon, says Vescelus, and hopes to choose one by the end of the year. To build and launch one of these instruments will cost between $200 and $400 million, he estimates. A lunar observatory, ASEPS' possible culmination, would cost billions.

There is at least one wild card that may force NASA to reconsider how it proceeds with ASEPS. A relatively new astronomical technique called adaptive optics offers space-like images from the ground, using a rapidly deformable secondary mirror to compensate for the atmospheric distortion of incoming light. And in the 17 March issue of *Nature*, Roger Angel of Steward Observatory at the University of Arizona calculates that current large telescopes, such as Keck, can already directly image Jupiter-sized planets around nearby stars if astronomers push adaptive optics to its limits. Why then focus so much on indirect detection? Angel asks. "I find it more appealing to make the direct images," he says. That thought hasn't been lost on NASA, says Rahe; ASEPS is already providing some $1 million a year to help develop this new technology. The program, like the mirrors in adaptive optics, intends to be flexible.

–J.T.

lier than expected, other times later. A statistical analysis showed periodicities in the timing data. Wolszczan then concluded that the pattern was produced by the gravitational pull of two orbiting planets on the pulsar. The star consequently "wobbles back and forth, so the pulses get periodically delayed and advanced," he says.



Pulsar planets. Gravitational tugs *(red)* affected the planets' orbits, altering the pattern of radio signals from the pulsar.

Though Wolszczan had few doubts, some in the astronomical community have been cautious in accepting their claim—they pointed to an earlier pulsar planet that turned out to be a mistake (*Science*, 24 January 1992, p. 403). But the presence of more than one planet in this case—the timing data reveals two bodies about three times the mass of Earth with orbits of 67 and 98 days respectively—offered the potential for an elegant proof. Rasio and others immediately calculated that the pull of the planets on each other should significantly alter their orbits. The affect of these changing orbits on the star's wobble would also be detectable within the arrival times of the star's pulses.

These perturbations, however, are orders of magnitude more subtle than the ones that originally revealed the planets. For statistical validity, concluded astronomers, the pulsar would have to be monitored for quite some time. "I thought it would take 5 years to dig out—if at all," says Wolszczan. But by this January, with only 3 years of data in hand, he was ready to claim success. A primary reason for the quick triumph was the fortuitous 3:2 ratio of orbital periods of the planets. The planets thus pass each other fairly frequently at the same place in relation to the pulsar. "The inner planet is getting a kick from the outer planet—and vice versa—in the same place," says Thorsett. This alignment sped up the orbital changes enough that they became quietly evident; otherwise, "it might have been centuries," he says.

Even though two planets are already safely in pocket, astronomers are far from finished with this pulsar system. Wolszczan now says the timing data point to a third orbiting body—a moon-sized object that circles the star every 25 days— as well as hints of a fourth with a much larger orbit. Attempts to image the planets have failed, though that failure was not unexpected. "It's probably just too far away for optical and infrared measurements," says Wolszczan.

Confirmation of the existence of the pulsar planets has given a welcome lift to those wondering whether our solar system is a rare event and planning searches for other planets (see box, p. 506). "I'm personally very impressed with the pulsar planet work," says University of Arizona's Donald McCarthy, a veteran planet searcher. Indeed, "if pulsars have planets, then almost anything can," says Thorsett, referring to the fact that most astronomers had considered pulsars unsuitable planetary homes, since they're the remnants of stars that have exploded in supernovae. The blasts would presumably have destroyed existing planets along with any material from which future planets might condense.

Or would they? Thorsett and Rachel Dewey at NASA's Jet Propulsion Lab calculated last year that preexisting planets might occasionally ride out the blast, depending on where their orbits placed them at the time of the supernova.

That kind of luck may not even be necessary to explain Wolszczan's and Frail's planets; their pulsar is a relatively old one, thought to have spun up by accreting material from a now-invisible companion. Such systems would have plenty of time to recover from a supernova, say astronomers. Moreover, the companion could have provided the seeds of future planets, says Rasio. Astronomers have observed a number of "eclipsing pulsars" where the pulsar boils material off its stellar companion. This freed material could then form a circumstellar disc, from which planets are thought to form.

Wolszczan himself is keen on another explanation: a cataclysmic merger of two inward-spiraling white dwarf stars, which would produce a pulsar—and possibly a circumstellar disk. At the moment, almost any explanation can have its partisans, since there's little data with which to weed out theories. "I haven't seen a real consensus forming," says Princeton's Joseph Taylor, who shared last year's Nobel prize in physics for his studies of pulsar timing. Most researchers do agree on one thing: These planets aren't likely to vanish into thin air as have so many others.

–**John Travis**

CARDIOVASCULAR DISEASE

Gene Transfer to Spark a Failing Heart

Just as the walled cities of ancient times had sentries at the gates, the cell has it own molecular sentries—proteins called receptors embedded in the cell membrane. These sentries consent to deal with only a few of the thousands of molecules that bathe the cell. As a result, those chosen few—hormones and other key messengers—have their messages passed along to the cell interior, where they receive a response. The past decade's leaps in understanding how these cellular sentries do their job may soon allow researchers to apply that knowledge to a surprising practical realm: gene therapy for congestive heart failure.

On page 582, receptor biologist Robert Lefkowitz of Duke University School of Medicine and his colleagues report that giving mice extra copies of the human gene for a specific cellular receptor (the β_2-adrenergic receptor, which responds to adrenaline) greatly strengthens the beating of the animals' hearts, even in the absence of adrenaline. "The result is really exciting, and it may ultimately give us a better understanding of how congestive heart disease progresses," says cardiologist Michael Bristow of the University of Colorado Health Sciences Center in Denver.

That understanding might one day also become a practical form of therapy for the condition, which results when the heart muscle cannot contract with enough power to circulate blood efficiently. Although congestive heart failure may be treated with adrenaline-like drugs, the patients' hearts respond weakly both to the drugs and to adrenaline itself. And as the heart continues to weaken, the drugs may become even less effective. But the Duke group's work suggests that it may be possible to reduce—even eliminate—use of drugs in therapy by introducing extra copies of the gene for the β_2-adrenergic receptor (β_2-AR) into a failing heart.

Lefkowitz decided to undertake the transgenic mouse experiments, he says, because Colorado's Bristow had shown that the β-adrenergic receptors are less abundant and less active in the hearts of congestive heart failure patients. He therefore reasoned that increasing the number of β_2-AR might well improve the heart's performance.

For their first experiments, the Duke group introduced into mice the gene for a β_2-AR mutant that constantly sends its signals to the cell interior, assuming this would be the most efficient way to aid the heart. However, these animals' hearts didn't have very many of the mutant receptors. Speculating that the heart cells couldn't tolerate the mutant receptor, the group introduced the normal β_2-AR gene into another batch of mice—with much better results. These animals showed anywhere from a 100- to 200-fold increase in β_2-AR expression. "I was blown away by how high the expression was," Lefkowitz says. The high expression