The first evidence of new Earth-like planets

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Very little attention has been paid in the media to a remarkable scientific discovery announced in late April by two teams of astronomers, working independently at observatories in Hawaii and in Chile.

For the first time, evidence has been found for the existence of rocky Earth-like planets outside our own solar system — a discovery that has broad implications for the study of the formation of planetary systems, and for the possibility of extra-terrestrial life forms.

Using highly sensitive equipment for detecting infra-red radiation, both groups of astronomers were able to photograph a disk of dust and gas surrounding a star known only as HR 4796A, at a distance of about 220 light years from Earth. The image and the NASA news release are available at http://www.jpl.nasa.gov/releases/98/hr4796.html.

HR 4796A, in the southern constellation Centaurus, is roughly 20 times more luminous than the Sun, a few times more massive and is part of a binary system — two stars revolving around one another. For a star, it is comparatively young — only 10 million years old — and may, according to some theories, be of the right age to be forming planets within the dust disc.

"With HR 4796, we're seeing a picture of a young adult star starting its own family of planets. This may be what our solar system looked like at the end of its main planetary formation phase," wrote Michael Werner from the NASA Jet Propulsion Laboratory, who worked at the giant 10-metre Keck II Telescope on Mauna Kea, Hawaii.

Lee Hartman, part of a team using the 4-metre Blanco Telescope at the Cerro Tololo Inter-American Observatory in La Serena, Chile, pointed to more specific evidence. "It was known that the primary star was surrounded by a dust cloud with a hole in it. Our images show that the cloud is indeed a disk, so that the hole could be cleared out by the gravity of one or more inner planets."

This conclusion, although still very tentative, is reinforced by the observation of disks of dusty debris around three nearby stars — Formalhaut, Vega, and Beta Pictoris — by another group of British and American astronomers, released in *Nature* magazine last month.

In the case of Formalhaut, the dust disk takes the form of a huge doughnut-shaped ring with a hole about the size of Neptune's orbit around the Sun. "The lack of bright emission close to the star suggests that dust is largely cleared out, and a probable explanation is that it has formed into rocky planets like the Earth, even though we cannot detect these directly," team leader Wayne Holland said.

While no holes have been observed in the dust disks surrounding Vega and Beta Pictoris, the total mass of the dust debris is estimated to be only a few times that of the Moon, suggesting that some planets may have already formed.

For decades, distant planets and remote alien civilisations have been the subject of scientific speculation and science fiction. After all, given the immense scale of the universe, it is highly likely that other worlds and other life forms exist.

Until recently, however, astronomers had no evidence that planetary objects existed outside the solar system. Because of the vast distances involved, formidable technical difficulties confront scientists attempting to find what are now known as extrasolar planets.

The last planet to be found in our own solar system was Pluto, first observed directly only in 1930, as a result of theoretical calculations predicting its existence. Pluto orbits the Sun at an average distance of 5.8 billion kilometres.

The closest star, Proxima Centauri, is 4.2 light years away — nearly 7,000 times the distance from the Sun to Pluto. Furthermore, the amount of light emitted by a star like the Sun is about a billion times greater than that reflected by any planet. At such distances, even the most sensitive optical telescopes are unable, at present, to make any direct observations of extrasolar planets.

Such are the technical complexities involved in finding small, Earth-like planets that an article written only last July in *Physics World* reviewing recent discoveries, concluded that "this challenging task will probably be within the reach of our technology within the next decade."

It is a testimony to the ingenuity of scientists that with shrinking budgets, especially for research which is unlikely to make an immediate profit, the first indications of small rocky planets were found less than a year later.

The key to this development is the fact that in the infra-red region of the electromagnetic spectrum, the conditions for detecting planets are far more favourable than with light. At certain wavelengths, for instance, Jupiter is only 10,000 times dimmer than the Sun.

By carefully selecting the infra-red wavelength to be observed, and constructing highly sensitive detectors, the teams were able build up a "photograph" which distinguished the small amounts of radiation emitted from dust particles and debris rotating around the stars.

The observations of Formalhaut were made with a new type of camera built by the Royal Observatory in Edinburgh, used in conjunction with the huge James Clerk Maxwell telescope in Hawaii. Known as SCUBA (Submillimetre Common User Bolometer Array), the camera consists of a series of detectors cooled to within one tenth of a degree above absolute zero (minus 273 degree Centigrade).

Scientists are confident that instruments of this type, which can detect infra-red radiation in a range previously little explored, will quickly lead to many similar discoveries.

The discovery of extrasolar planets has developed swiftly over the last four years, since the first planet-like object was detected in 1994 by Alexander Wolszczan and Dale Frail. Until now, however, the discoveries have involved massive planets, comparable in size to Jupiter, the largest in our solar system.

All of the finds have been based on observations of the same basic effect: that the gravitational influence of planets orbiting a star will cause it to "wobble". One method of detecting the "wobble" is by what is known as the Doppler effect. To take a common example: when an ambulance is moving towards an observer the pitch of its siren is higher than when it is moving away. Similarly, the gravitational pull of an unseen planet causes a star to fractionally speed up or slow down relative to the Earth, causing a minute shift in the frequencies of radiation emitted by the star.

Such an effect was observed by Wolszczan and Frail, who studied the tiny variations in the arrival times of radio pulses from pulsar PSR 1257+12 over a three-year period and concluded that three planets were rotating around it. From the way the pulsar "wobbled" they could determine the mass and orbits of each of the planets.

But pulsars, or neutron stars, are strange astronomical objects — the collapsed, ultra-compact remnants of super nova explosions which rotate, often at high speed, sending out a highly concentrated beam of radio waves. A number of astronomers were highly dismissive of the find because it did not involve "genuine" planets rotating around "normal" stars like the Sun.

However, in October 1995, Michel Mayor and Didier Queloz of the Geneva Observatory in Switzerland announced the detection of Doppler shifts caused by a planet about half the size of Jupiter rotating around a solar-type star, 51 Pegasi.

The planet is very odd. It orbits at a distance of just seven million kilometres from its star — less than one eighth Mercury's distance from the Sun — and thus its surface is theoretically baked to a temperature of 1,300 degrees Centigrade. So fast is its rotation around the star that its "year" is just four days long.

Since then, a growing number of extrasolar planets have been discovered using similar techniques, sparking a sharp controversy. Last year David Gray of the University of Western Ontario challenged the validity of the conclusions, claimed that the observed Doppler shifts may have been caused by the pulsations of stars, not by orbiting planets.

The debate has spilled over into the Internet. Gray's original arguments are available at http://astro.berkeley.edu/~gmarcy/51-peg.html and the reply of Mayor and US astronomer Geoffrey Marcy is at http://cannon.sfsu.edu/~gmarcy. In his latest article at http://phobos.astro.uwo.ca/~dfgray/51-Peg2.html, Gray now admits that "the planet hypothesis is now the front runner".

Of course, the debate is not over. No-one has yet photographed a family of planets orbiting a star. But the growing number of indirect observations, using a variety of different scientific techniques, point more and more clearly to the conclusion that many extrasolar planets exist, including those like our own planet Earth.

For those interested in following this exciting and rapidly expanding field of scientific research, a number of web sites devoted to the subject are listed at http://www.yahoo.com/Science/Astronomy/Extrasolar_Planets/.