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Explainer: How astronomers find exoplanets

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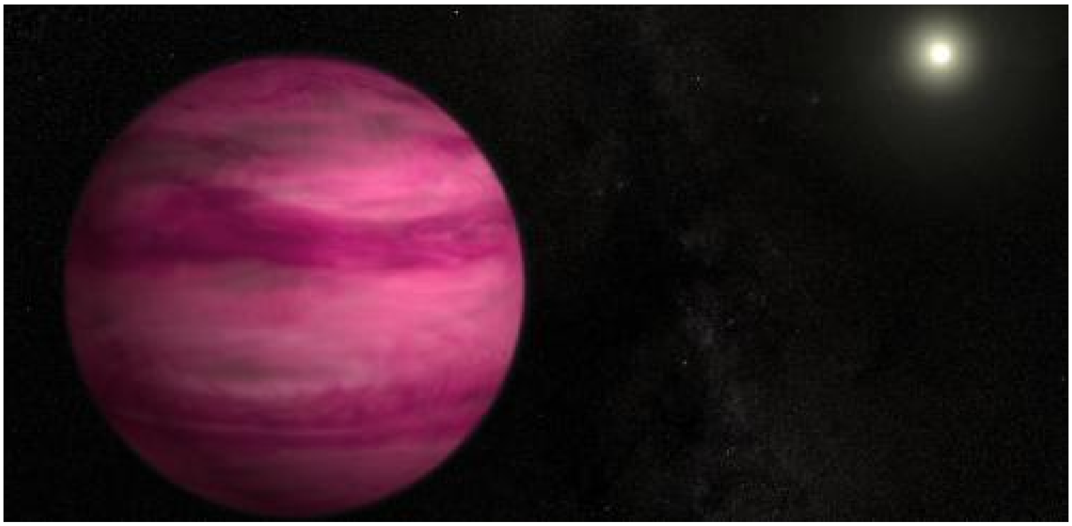

Maybe pink planets have life too. Credit: gsfc

Astronomers didn't know, 20 years ago, whether planets existed around any stars other than the Sun. All that changed in 1995 with the discovery of an exoplanet orbiting the star 51 Pegasi. And by the beginning of 2014, more than 1,000 exoplanets had been found. As a result, astronomers are now closer than ever to answering the question of whether life exists elsewhere in the universe.

Many people assume that astronomers "see" exoplanets directly through their telescopes, perhaps akin to the Earth as a pale blue dot sitting alongside a distant star. The reality is much stranger: in most cases, all that is seen is a single, stationary pin-point of light – the star itself. Yet by measuring the brightness of that speck of light, astronomers may see a tiny repeated dimming, as though the star is winking at us, indicating the transit of an exoplanet in front of the star, blocking a fraction of the light. But just from that faint light, we are able to find out a lot about the exoplanet.

With the help of simple methods and powerful telescopes, astronomers may infer that the star is wobbling back and forth, as it is tugged by the gravity of an exoplanet. From the depth of the "wink" and the amplitude of the "wobble", the size and mass respectively of the unseen exoplanet can be determined. This can give us its density and surface gravity which in turn tell us what the exoplanet may be made of.

It is also easy to determine the length of the exoplanet's year from the interval between repeated winks or wobbles. We can then calculate the distance of the exoplanet from the star and its temperature. In this way we can tell whether the exoplanet orbits the star within the habitable zone, where liquid water could exist on its surface.

But the extrapolation doesn't stop there. Most remarkably, when an exoplanet passes in front of a star, a tiny fraction of the starlight reaches us after it has passed through the exoplanet's atmosphere. This causes the chemical signature of that atmosphere to be imprinted during the transit. By studying the differences between the in-transit and out-of-transit data, it is possible to work out what the atmosphere of the exoplanet is made of.

Ultimately, it is measurements like these that will tell us whether or not humankind is alone in the universe. Many astronomers are confident that the detection of biomarkers in the atmosphere of an Earth-like exoplanet will happen within the next 20 years – if life actually exists elsewhere in the Milky Way galaxy. It may only be a green slime that could be scraped off a rock with a finger nail, but it would transform humanity's view of its place in the Universe.

By 2014, more than 400 exoplanets had been found by the transit method, using ground-based telescopes such as SuperWASP or satellites such as Kepler. The Kepler satellite also found many thousands of candidate transiting exoplanets, but the problem with these is that they orbit stars too faint for us to measure the stellar wobble that an exoplanet would produce. With only the wink observed, we can't work out the exoplanet mass, and the transit signal could actually be caused by something else, for example another star.

This month, the Kepler team announced it had found 700 new transiting exoplanets around 300 stars. All these are multi-planet systems, where more than one exoplanet passes in front of the star, producing multiple winks. The team members argue that, even though the stars are too faint to measure the wobble, these must be exoplanets because there is no other way of producing the multiple winks in each case.

Many of the known exoplanets are Jupiter-like gas giants in very close, short-period orbits around stars, but increasingly a number of Neptune-like exoplanets have been found too, including some in longer orbits. Most of the new Kepler discoveries in multi-planet systems are Neptune-sized or smaller, however we don't know the mass of any of them.

So far, no rocky, Earth-sized, Earth-mass planet has been found in the habitable zone of a Sun-like star. To find one would require sensitive and long observations (capable of detecting a 0.01% dip in starlight) of the same star continuously for several years to detect a transit that lasts for just a few hours and repeats only every year or so.

Also, to stand a chance of finding truly Earth-like exoplanets, astronomers must observe huge numbers of stars that are bright enough to measure the resulting Doppler shift. That is what the PLATO satellite mission will do when it is launched in ten years' time.

PLATO stands for Planetary Transits and Oscillations of Stars and it will observe a million bright stars during its six year lifetime. Using its on-board array of 34 individual telescopes, PLATO will stare at a huge area of sky at any one time – around 100 times the diameter of the full Moon – and so cover half the sky during the mission.

Not only will it find planets through the periodic dimming of starlight caused by a planet passing in front of the star, PLATO will also measure tiny changes in starlight caused by vibrations in the host stars, performing so-called asteroseismology. Just as in seismology of the Earth, these vibrations reveal the interior structure of the vibrating body. In particular, asteroseismology tells us the age of the vibrating star and hence that of the planets orbiting around it. So astronomers will be able to fully characterize the hundreds of planetary systems that PLATO will discover.

Some of the planets discovered by PLATO will be rocky Earth-like planets in the habitable zones of the Sun-like stars they orbit. As a result, within the next 20 years, we may finally find the first evidence of life beyond our blue planet.

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