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editorial

Brave new worlds?

Twenty-five years ago, the detection of the first extrasolar planets opened up an area of research that has fascinated both researchers and the general public alike.

Are we alone in the Universe? This oft-posed question is a loaded one. Given the billions of stars in our own Galaxy, surely life must exist somewhere beyond our planet. And what exactly do we mean by life? For Earth-based lifeforms that we know, liquid water and sufficient gravity to hold onto an atmosphere are required, at the very least. These conditions define the ideal distance (the 'Goldilocks' zone of habitability) between a planet and its star as well as a minimum planetary mass. On the occasion of the twenty-fifth anniversary of the discovery of the first extrasolar planets, we look back and ahead.

In 1992, the detection of two (of the three) planets around pulsar PSR B1257+12 (ref. [1]) enabled us to begin to address the question on a scientific basis (not that the lack of hard evidence discouraged any discussions before). The pulsar had only been discovered in 1990 by Aleksander Wolszczan, and its irregular pulsation period revealed the first extrasolar planets. Three more years passed before Michel Mayor and Didier Queloz found a Jupiter-mass planet orbiting a Sun-like star, 51 Pegasi. However, its close-in orbit — well within the radius of Mercury, for instance — did not fit models of planet formation. Did it form elsewhere and migrate inward, or was it formed by the stripping of a brown dwarf? And would 51 Pegasi b be able to sustain an atmosphere? In order to study exoplanet atmospheres, radial velocity measurements are not enough. The planet has to transit across its star.

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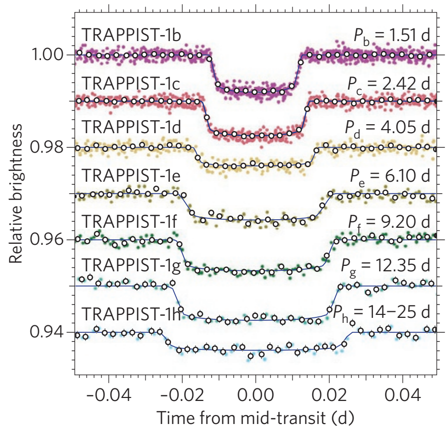
The first such transiting exoplanet was observed in 1999. A slight dip in the light curve was measured as part of the star was eclipsed. From the change in the measured starlight, we get the mass ratio between the planet and the star. Molecules in a transiting planet's atmosphere absorb the light emitted by the star behind it, so we can glean information on the composition of the atmosphere through spectroscopic measurements. With this method, planetary scientists and chemists have joined forces with astronomers. When will the biologists have their day? In 2015, the first potentially rocky exoplanet within the habitable zone of its star, slightly older and larger than the Sun, was announced[2]. But the presence of life is still pure speculation. When scientists speak of the habitable zone, the computations are for an Earth clone, and for a given exoplanet, we don't know whether there's ozone to shield the planet from ultraviolet radiation, a magnetic field or geological activity.

So where are we now? We have a list of over 3,500 confirmed exoplanets, among them a seven-planet system around a cool dwarf star, TRAPPIST-1[3]. Dynamically, this system is more like Jupiter and its moons than the Sun with its planets (see article no. 0104 for more details). Fortunately, all seven of the planets (labelled b through h) are transiting its star, making the study of their atmospheres possible (a sample light curve measurement is pictured; reproduced from ref. [3], Macmillan Publishers Ltd). Moreover, the six inner planets are likely rocky and five of them have Earth-like masses. And if that wasn't enough, planets e, f and g could harbour surface water, as could b, c and d, albeit over a smaller area. Cue the ensuing media excitement. But do hold off planning any holidays just yet (despite NASA's vintage-style travel poster; pictured). We don't know if any of these TRAPPIST-1 planets have atmospheres. K2 has just released the raw data for Campaign 12, including 79 days of TRAPPIST-1 observations, so there may be information forthcoming.

To date, the Kepler and K2 missions, and the High Accuracy Radial velocity Planet Searcher (HARPS) spectrograph on the ESO's 3.6-m telescope have found the most exoplanets, and rocky planets in the habitable zone only make up about 1% of them. Coming up in 2018, there's the CHaracterising ExOPlanet Satellite (CHEOPS) for probing known exoplanetary systems, the Transiting Exoplanet Survey Satellite (TESS) to survey the nearest and brightest stars for exoplanets and the James Webb Space Telescope for more detailed atmospheric characterization and direct imaging using coronagraphs.



In general, apart from detection, we are starting to characterize exoplanets — even observing clouds on Gliese 1214 b (a candidate for an oceanic planet[4]) and 'weather' on HAT-P-7b, a hot gas giant[5]. Further understanding will come from more observations, but we also need more sophisticated models and interdisciplinary collaborations with experts on climate, clouds and aerosols. Moreover, it will be critical to assess whether and how atmospheres affect measurements. Additionally, there are factors that have only begun to be considered: the effect of tidal locking, star activity and its solar wind, magnetospheres, plus exomoons and exocomets. It is also clear that the Solar System is not the standard planetary model. What an exciting time for exoplanetary science! ❐

References

1. Wolszczan, A. & Frail, D. A. *Nature* **355,** 145–147 (1992).
2. Jenkins, J. M. *et al. Astron. J.* **150,** 56 (2015).
3. Gillon, M. *et al. Nature* **542,** 456–460 (2017).
4. Charbonneau, D. *Nature* **462,** 891–894 (2009).
5. Armstrong, D. J. *et al. Nat. Astron.* **1,** 0004 (2016).