Our place in the Universe

As *Nature* turns 150, we look back on its close connection to the Nobel Prize in Physics and some of the most epoch-defining papers in astronomy.

This month we are celebrating *Nature*'s 150th birthday. The founder and first editor was the astronomer Norman Lockyer. He was particularly interested in solar physics, which was all the rage in 1869. In fact, in the launch issue Lockyer wrote an article referring to the corona as "bizarre and puzzling" — at the time, there was no consensus as to whether the corona was a part of the Sun or an effect due to Earth's atmosphere or some such illusion; not that long ago Johannes Kepler and Edmond Halley thought it was somehow related to the Moon! Although we now know it to be part of the Sun, just how the corona gets so hot remains a topic of intense debate.

Since 1869, many astronomical discoveries have been introduced in *Nature*. For example, Franco Pacini predicted that a rotating neutron star with a magnetic field would emit a detectable beam of light a year before Jocelyn Bell, Antony Hewish and three others reported the discovery of a pulsing radio source. It was Thomas Gold who noticed the two phenomena where one and the same: a pulsar.

Pulsars have continued to make headlines, not least because Aleksander Wolszczan and Dale Frail found the first confirmed extrasolar planet — actually a pair of them! — orbiting a millisecond pulsar in 1992. However, the real sensation occurred three years later with the discovery of a Jupiter-mass planet around a Sun-like star by Michel Mayor and Didier Queloz, which kick-started a concerted search effort that has so far yielded more than 4,000 exoplanets. The closing paragraph of their Article in *Nature* satisfyingly proclaims the new era: "The search for extrasolar planets can be amazingly rich in surprises. From a complete planetary system detected around a pulsar to the rather unexpected orbital parameters of 51 Peg b, searches begin to reveal the extraordinary diversity of possible planetary formation sites."

The early detections mostly involved hot gas giants in close orbits around their host stars due to the detection technique (radial velocity). With the launch of the Kepler mission (and the method of planetary transit), designed to find exoplanets with masses between those of Earth and Neptune, we soon learned that planets outnumber stars. Moreover, 20–50% of the stars in our Galaxy likely have rocky planets at the right distance for liquid water to exist on their surfaces. Although Kepler (and K2, its follow-on mission) has retired, TESS is currently surveying the whole sky for exoplanets that pass in front of their stars, causing a temporary dip in brightness. This mission will find a more diverse set of exoplanets than Kepler. Next month CHEOPS will be launched in order to characterize exoplanets around known planet-hosting bright stars.

In just over two decades, we've gone from finding the first exoplanet to being able to detect molecules in their atmospheres, including water vapour. It's no wonder that one-half of the 2019 Nobel Prize in Physics was awarded to Mayor and Queloz. They have truly opened up our world. Our Solar System has no planet that is larger than Earth but smaller than Neptune, yet this is the most common type of planet in the Galaxy. Are we the outlier? In any case, we need to reconsider our theories of planetary system formation.

The other half of the physics Nobel Prize this year went to James Peebles for his work on physical cosmology. Back in the 1950s, the idea that the Universe had a beginning and that it then expanded from this hot, dense state was not fully recognized. Bob Dicke's group set out to look for the remnant thermal radiation of a few kelvin, and his student Peebles was working on the implications of finding (or not finding) this radiation. Unfortunately for them, Arno Penzias and Robert Wilson found it first, though they didn't know what it was. They had detected the 2.7 K cosmic microwave background (CMB) left over from the hot early Universe after the Big Bang.

Peebles would go on to develop analytic and numerical simulations of galaxy formation to turn cosmology into a precision science over the next decade. Being able to constrain the amount of matter in the Universe revealed the need for some exotic, non-baryonic form of matter to hold galaxies together. In 1982, Peebles introduced non-relativistic cold dark matter to explain structure formation as a consequence of anisotropies in the CMB. He also resuscitated the cosmological constant, Λ, on physical grounds (the measured matter density was not enough to lead to a flat Universe, so inflation made sense). Both of these predictions were spectacularly confirmed, respectively, by observations of CMB anisotropies by the Cosmic Background Explorer (COBE) and by measurements of the acceleration in the expansion of the Universe using type 1a supernovae as standard candles that were dimmer than expected.

Peebles describes the heyday of the development of the Λ cold dark matter theory in a Perspective. For other relevant papers on physical cosmology and exoplanets that *Nature* has published in the past 150 years, please see our Nobel Prize in Physics 2019 Collection.

But let us not rest on our laurels. We aim to keep publishing the kind of research that opens our eyes to the marvels of the Universe and our place within it. Take the five papers concerning Voyager 2 in this issue of *Nature Astronomy*. They confirm that the spacecraft left the plasma bubble of the heliosphere and entered the interstellar medium on 5 November 2018, after travelling for 41 years. Unlike Voyager 1, which made a similar crossing seven years ago, readings from the instruments on Voyager 2 suggest a thinner and smoother heliosphere boundary with a stronger interstellar magnetic field beyond. In one paper, for example, John Richardson and colleagues suggest that the transition through the heliopause occurred in less than one day and the interstellar medium closest to the boundary is much hotter and more variable than expected. In another study, Edward Stone and co-authors report observations indicating a layer between the heliopause and interstellar space where solar and interstellar winds interact. Such a layer was not observed by Voyager 1.

Whether the differences are due to changes in the solar cycle or variations in the structure of the heliopause (the outermost part of the heliosphere) is an open question that requires more data. Will there be another mission to break out of the Sun's bubble? Well, the film *Star Wars* was released the same year as the Voyager launches, and created a generation that can picture a sunset on a world with two suns. We now know those worlds exist. Surely, like Tennyson's Ulysses, it is imperative for us "to strive, to seek, to find, and not to yield". ❐

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