# Evolution of the universe and Earth's place in cosmos – The 2019 Nobel Prize for Physics

This was an unusual Nobel prize in that it was awarded 'for contributions to our understanding of the evolution of the universe and Earth's place in the cosmos'. This is a broad area which could include almost anything in astronomy. James Peebles was awarded one half of the Prize 'for theoretical discoveries in physical cosmology' which was really a recognition of a lifetime of work while Michel Mayor and Didier Queloz won the other half of the Prize 'for the discovery of an exoplanet orbiting a solar-type star': a very specific if notable discovery. While undeniably deserved, either award could have been given anytime in the last 25 years for the exoplanet discoveries and 50 years for the cosmology work.

Phillip James Edwin (Jim) Peebles was born in a suburb of Winnipeg, the only city in the province of Manitoba in Canada, on 25 April 1935. He went to a small school there and then to the University of Manitoba where he started in the engineering school. Like many of us, he did not find engineering very exciting and switched to physics in his third year. Then, as now, the University of Manitoba was largely a teaching institution and it was not until he joined Princeton that he learnt about new areas in research. After a brief flirtation with particle physics, he joined Robert Dicke's group on gravity physics. Bob Dicke played a major role in Peebles' career and his admiration and gratitude to Dicke is clear, even now. Dicke, himself, was one of those rare talents who was primarily an experimentalist and an instrument builder but with the theoretical foundation to create new areas of physics. Peebles received his Ph D in 1962 under the supervision of Dicke and has remained at Princeton ever since. He is now the Albert Einstein Professor of Science, Emeritus.

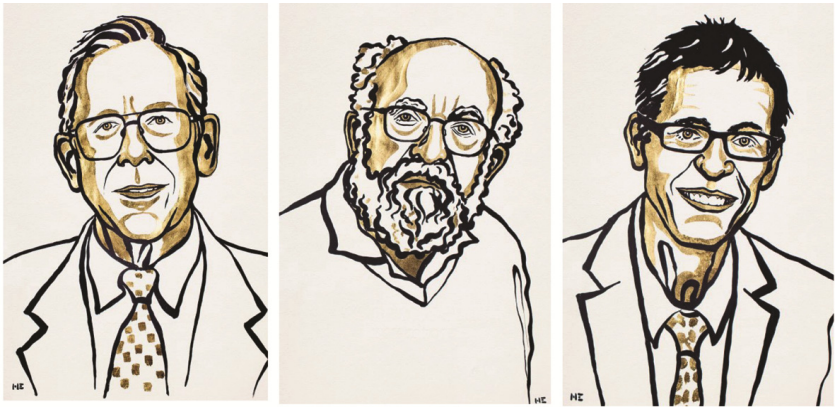
Peebles first began his work in physical cosmology with a work suggested by Dicke. Dicke had been exploring the idea of an oscillatory universe in which the heavy elements from one universe would have been destroyed by the high temperatures of the next. Although not particularly interested or convinced by the idea, Peebles did work out the radiation due to the hot Universe and predicted the existence of the microwave background. In the now well-known story, Peebles gave a talk on his subject at the Applied Physics Laboratory of the Johns Hopkins University following which Arno Penzias and Bob Wilson contacted Dicke for help in understanding the mysterious noise picked up by their radio dish at Bell Labs. Penzias and Wilson were awarded the Nobel Prize in 1978 for the discovery of the cosmic microwave background and it seems only fair that Dicke should have had a share in the prize (it went to Kapitza, who was certainly a deserving recipient).

Peebles has had an outstanding career focused on physical cosmology and has played an important role in moving the field from speculation into the firm models and predictions that we have today. He has discussed how he was always unsure of the basic axioms of cosmology, namely isotropy and homogeneity to the point where he felt it was unrealistic to have a theory of the Universe. He played a major role in showing not only that such a theory made sense but in putting together the framework for that theory. He was amongst the first to run computer simulations of the cosmic structure formation. This is now a core research area in astronomy with each new model greeted with great enthusiasm. Peebles has made contributions to more areas of cosmology than can be discussed here and I will close by simply mentioning his contributions to dark matter, dark energy, inflation and galaxy evolution.

Over the years, he has been awarded a number of medals and prizes including the Heineman Prize, the Gold Medal of the Royal Astronomical Society, the Gruber Prize, the Crafoord Prize and, now, culminating with the Nobel Prize. Along the way, he has published several books, including the *Principles of Physical Cosmology* which has taught many people physical cosmology. Jim Peebles has truly been awarded the Prize for his entire life's work.

The other half of the prize was shared by Michel Mayor and Didier Queloz for the specific discovery of the first planet around a main sequence star in 1995. The first planet had been discovered only a few years earlier by Wolszczan and Frail through observations of pulsar timing, but pulsar environments are notably inhospitable. Mayor had been working on high resolution spectroscopy for radial velocity measurements and when, with Queloz, he turned his attention to 51 Pegasi, they were found the first planet around a normal-type star, opening the floodgates of exoplanet detections.

Michel Gustave Édouard (Michel) Mayor was born in Lausanne, Switzerland on 12 January 1942. He obtained an M Sc from the University of Lausanne in 1966 and a Ph D from Geneva Observatory in 1971. He spent most of the next four decades at Geneva Observatory becoming Director of the Geneva Observatory in 1998. He retired in 2007 but, of course, continues to do ground-breaking research at the Observatory.



James Peebles | Michel Mayor | Didier Queloz

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Didier Queloz was born in Neuchâtel, Switzerland on 23 February 1966 and completed his undergraduate and graduate education at the University of Geneva, and still holds a professorship there. He joined the Cavendish Laboratory of the University of Cambridge in 2013 as a professor and has been there since.

Mayor had been working on more accurate ways to determine radial velocities and over the years developed spectrometers that could measure velocities first at levels of a few km/s and then, after Queloz joined, to levels of a few metres/s. The culmination of their work was the ELODIE echelle spectrograph. The student (Queloz) had been using the spectrograph to look at radial velocity measurements of the Sun-like star 51 Pegasi, which is a (barely) naked eye star about 50 light years from the Sun. He found that the star was jiggling back and forth with a peak velocity of about 50 m/s and, after convincing themselves that their answer was correct, Mayor and Queloz published their paper in *Nature* as 'A Jupiter-mass companion to a solar-type star', a publication with over 2300 citations. Despite initial scepticism, this result was soon confirmed by Butler and Marcy using the Lick Observatory and the floodgates opened for exoplanet discovery, with the deluge coming after the flights of Kepler and now TESS, which is finding 50 exoplanets a month.

It is hard to overstate the impact of the 51 Peg discovery. The paradigm for planetary systems had been our own Solar System with its very organized nine planets: four rocky planets near the Sun and four gassy planets far away plus Pluto. It was still an open question whether there were planets around other stars at all and Frank Drake's famous equation only put planets around 50% of other stars. Now, not only was one other system found but it was a very different system with a hot Jupiter, a Jupiter-sized planet where Mercury should have been. Soon many more such systems were found and it became clear that our system was unusual in being so apparently normal. Exoplanets were a career-ending field when Mayor and Queloz found 51 Peg b; now no proposal can be put in without stating its impact on exoplanetary studies and, even more, on searching for extra-terrestrial life.

Mayor and Queloz have both had productive careers after their discovery with contributions to other instruments and programmes but, in their case, the Nobel was awarded strictly for this one discovery that opened up the entire field. Without 51 Peg b, there would have been no Kepler and no TESS.

Winning the Nobel prize is a matter of chance. There are many who deserve the Prize but did not get it – E. C. G. Sudarshan springs to mind. As I said earlier, this Prize could have been given long back and, if it had been given five-years ago, the late Vera Rubin would have been a strong candidate for her pioneering work in dark matter. It is a shame that so few women have been recognized for their work and it would have made a strong statement if the Committee had not overlooked such a deserving candidate.

I can do no better than to close with Peebles own words: winning awards and prizes are 'very much appreciated' but one should 'enter it [science] for the love of the science.'


1. Peebles interview with Alan Lightman: https://www.aip.org/history-programs/niels-bohr-library/oral-histories/33957
2. Peebles interview with Martin Harwit: https://www.aip.org/history-programs/niels-bohr-library/oral-histories/4814
3. Princeton announcement of Nobel Prize: https://www.princeton.edu/news/2019/10/08/princetons-james-peebles-receives-nobel-prize-physics
4. James Geach in the Conversation: https://theconversation.com/nobel-prize-in-physics-james-peebles-master-of-the-universe-shares-award-124916
5. A Jupiter-mass companion to a solar-type star by Mayor & Queloz: https://www.nature.com/articles/378355a0
6. Queloz website at Cavendish: https://www.astro.phy.cam.ac.uk/directory/prof-didier-queloz
7. Announcement: https://www.nobelprize.org/prizes/physics/2019/prize-announcement/


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