KUNGL. VETENSKAPS-AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2019 "for contributions to our understanding of the evolution of the universe and Earth's place in the cosmos" with one half to **James Peebles** "for theoretical discoveries in physical cosmology" and the other half jointly to **Michel Mayor** and **Didier Queloz** "for the discovery of an exoplanet orbiting a solar-type star".

The Nobel Prize 2019 **in Physics**

Our place in the universe

This year's Nobel Prize in Physics rewards new understanding of the universe's structure and history, and the first discovery of a planet orbiting a solar-type star outside our solar system.

James Peebles' insights into physical cosmology have laid a foundation for the transformation of cosmology over the last fifty years, from speculation to science. His theoretical framework, developed since the mid-1960s, is the basis of our contemporary knowledge about the universe.

It all began almost 14 billion years ago, when the universe was extremely hot and dense. Since then, the universe has been expanding, becoming larger and colder. Barely 400,000 years after the Big Bang, the universe became transparent and light rays were able to travel through space. Even today, this ancient radiation is all around us and, coded into it, many of the universe's secrets are hiding. Observations of this radiation showed us a cosmos in which just five per cent of its content of energy and matter is known, the matter which constitutes stars, planets, trees and us. The rest, 95 per cent, is unknown dark matter and dark energy. This is a mystery and a challenge to modern physics.

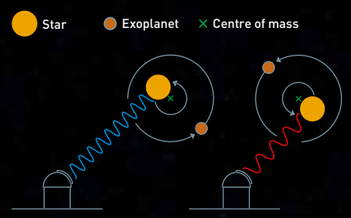
In October 1995, **Michel Mayor** and **Didier Queloz** announced the first discovery of a planet outside our solar system, an exoplanet, orbiting a solar-type star in our home galaxy, the Milky Way. At the Haute-Provence Observatory in southern France, using custom-made instruments, they discovered planet 51 Pegasi b, a gaseous ball comparable with the solar system's biggest gas giant, Jupiter.

This discovery started a revolution in astronomy and over 4,000 exoplanets have since been found in the Milky Way. Strange new worlds are still being discovered, with an incredible wealth of sizes, properties and orbits. They broaden our preconceived ideas about planetary systems and are forcing scientists to revise their theories of the physical processes behind the origins of exoplanets. With numerous projects planned to start searching for exoplanets, we may eventually find an answer to the eternal question of whether there is life out there.

This year's Laureates have transformed our ideas about the cosmos. While James Peebles' theoretical discoveries contributed to our understanding of how the universe evolved after the Big Bang, Michel Mayor and Didier Queloz explored our cosmic neighbourhoods on the hunt for unknown planets. Their discoveries have forever changed our conceptions of the world.

Radial velocity method

The star moves due to the gravitational attraction from its planet. Seen from the Earth, the star wobbles backwards and forwards in the line of sight. The speed of this movement, its radial velocity, can be determined using the Doppler effect, because the light from a moving object changes colour.

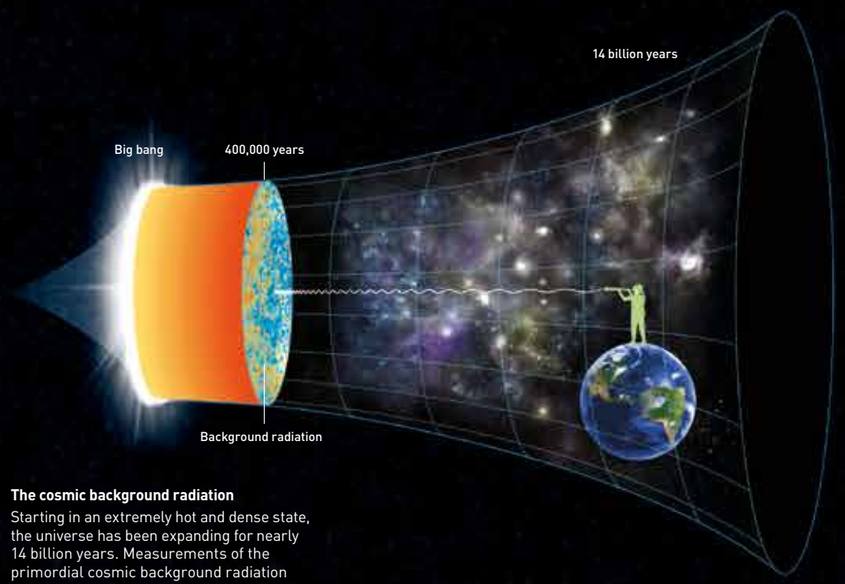


Light from an object moving towards us is bluer.

Light from an object moving away from us is redder.

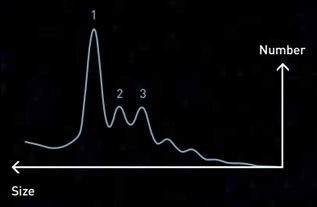
← The planet Pegasi 51 b. Big as Jupiter, and with a temperature of 1,000°C, it takes just 4.2 days to orbit its sun.

→ The star Pegasi 51. It is in the constellation of Pegasus, the flying horse, 50 light years from us and is visible to the naked eye when it is really dark.



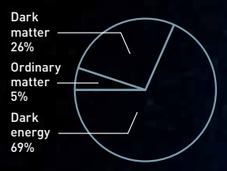
The cosmic background radiation

Starting in an extremely hot and dense state, the universe has been expanding for nearly 14 billion years. Measurements of the primordial cosmic background radiation result in a map of the contents of the universe. The spots show small temperature variations in the background radiation.



The curve shows how many spots there are of each size in the background radiation.

The first peak shows that the universe is not curved, it is geometrically flat. The second peak shows that ordinary matter is just 5% of the matter and energy in the universe. The third peak shows that 26% of the universe consists of dark matter.



From these three peaks, it is possible to conclude that if 31% (5%+26%) of the universe is composed of matter, then 69% must be dark energy in order to fulfil the requirement for a flat universe.

James Peebles
Born 1935 in Winnipeg, Canada. Albert Einstein Professor of Science at Princeton University, USA.

Michel Mayor
Born 1942 in Lausanne, Switzerland. Professor at University of Geneva, Switzerland.

Didier Queloz
Born 1966 in Geneva, Switzerland. Professor at University of Geneva, Switzerland, and University of Cambridge, UK.

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