

# Planet formation viewed by astronomers

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More than 200 years since Immanuel Kant and Pierre Simon Laplace first put forward the nebular hypothesis—which holds that our solar system evolved from a cloud of matter rotating around the sun—astronomers are now viewing discs around stars where planets are actually forming.

Using the Very Large Telescope (VLT) at the European Southern Observatory (ESO), astronomers can see a faint star, T Chamaeleontis (known as T Cha), in the southern constellation of Chamaeleon. The star is similar to our sun but much younger, about seven million years old, compared to the sun's age of four and a half billion years. It is surrounded by a disc of dust [1].

While many such discs have now been seen, the current study in two published papers has shown that the disc has a large gap in it. Some of the disc is in a narrow ring only 20 million kilometres from the star. By comparison the earth is 150 million kilometres from our sun. Then there is a gap with no dust, beyond which the outer part of the disc can be seen stretching out to 1.1 billion kilometres from T Cha.

With enormously powerful resolution—T Cha is 350 light years away—the team conducting the study managed to find a smaller object orbiting the star in the gap, apparently sweeping a path through the disc.

Whether this smaller object is a planet or a so-called brown dwarf surrounded by dust is yet to be determined. A brown dwarf is smaller than a star and without a fusion source of energy, but larger than Jupiter-type gas planets. Either way it is another milestone in the science of planetary evolution that has been developing at a tremendous rate in the last decade or so.

“Earlier studies had shown that T Cha was an excellent target for studying how planetary systems

form,” explains Johan Olofsson of the Max Planck Institute for Astronomy, Heidelberg, Germany, the leading author of the first paper in the study. “But this star is quite distant and the full power of the Very Large Telescope Interferometer (VLTI) was needed to resolve very fine details and see what is going on in the dust disc.”

Based at the Paranal Observatory on Cerro Paranal, a 2,635-metre-high mountain in the Atacama Desert in northern Chile, the VLT is made up of four telescopes which work as an array. The technique of interferometry uses the tiny differences between the images in the four telescopes to obtain very high resolution. It is said that the VLT could see the gap between the headlights of a car on the moon. Although each of the four telescopes is 8.2 metres across, the technology enables them to combine as a “virtual telescope” that is 130 metres across.

Whilst the VLT observed the dust disc, finding a companion object to T Cha in the gap in the disc required a further special technique that uses computer image processing, known as adaptive optics. This enables much of the blurring effect of the earth's atmosphere to be removed and obtain sharp images—in this case of a faint object next to a brighter one.

Nuria Huélamo of the European Space Astronomy Centre near Madrid, Spain, lead author of the second paper, said, “For us, the gap in the dust disc around T Cha was a smoking gun, and we asked ourselves: could we be witnessing a companion digging a gap inside its protoplanetary disc?”

The astronomers searched for the companion object at two different bands of the infrared spectrum and found it only at the band with a longer wavelength. It is this fact that tells them it is relatively cool, either a planet or a brown dwarf surrounded by dust.

“This is a remarkable joint study that combines two different state-of-the-art instruments at ESO's Paranal

Observatory,” Huélamo concluded. “Future observations will allow us to find out more about the companion and the disc, and also understand what fuels the inner dusty disc.”

The T Cha discovery is one of a number of recent advances in our knowledge of planetary formation [2]. Many of them are the result of the huge increase in knowledge about our own solar system that has come from explorations carried out by spacecraft. It has been possible to put instruments into orbit around planets and to land probes.

Our understanding of protoplanetary discs surrounding other stars, as well as exoplanets (planets outside our own solar system) has been increased both by terrestrial telescopes, like VLT and by those in orbit, like Hubble. These instruments have produced an explosion of observations, which are stimulating theoretical advances and the use of computer simulations to explore the process of planetary formation.

The original nebular hypothesis of Kant and Laplace was dominant in the nineteenth century, but it came up against problems in explaining planet formation in the course of the twentieth. It is now being revived on the basis of the Solar Nebula Disk Model (SNDM) that was pioneered in the 1970s and 1980s, especially by the Soviet astronomer Victor Safronov.

Its proponents argue that as the dense molecular cloud from which a star is formed collapses, a flattened and evolving protoplanetary nebula of gas and dust surrounds it. This dust coagulates to form pebbles which rapidly agglomerate into kilometre-sized “planetesimals”. Exactly how this happens is still not understood. The planetesimals accelerate the accretion process, drawing in more material under their gravitational attraction and forming protoplanets about the size of the Moon or Mars.

When the protostar at the centre of the original cloud grows so much that it ignites to form a star, the surviving disc is removed, leaving large numbers of protoplanets which can go through violent mergers. They may form small rocky planets, such as the Earth, Mars, Venus and Mercury in the case of our solar system. The formation of giant planets like Jupiter is apparently a more complex process, still only partially understood, with two competing theories attempting to explain it.

It is thought that the formation of planets is a comparatively rapid process in the development of young stars like T Cha. This is, so far, the only example of the process to have been observed.

Joseph Burns [2] explains that only four decades ago the motions of objects in our own solar system were thought to be rather like clockwork. They were regarded as entirely predictable in a narrow mechanical sense. This is no longer the case. It is now known that chaotic orbits mean that the paths of particles of rock through the solar system can be altered significantly, leading to collisions that can clear swathes through space.

“Accordingly chaos had a determining role in the Solar System’s accumulation and evolution, sculpting much of its visible architecture today,” he writes, “the contemporary solar system is continually changing.”

What is more, the results of planetary evolution are extraordinarily diverse. “It is difficult to choose a favorite among Saturn’s austere beautiful rings, Venus’s tortured volcanic plains or Triton’s icy elegance. These worlds, all following the same laws of physics and chemistry, are so different. Yet all are the Earth’s siblings, born from the same inter-stellar cloud at a similar time.”

Our understanding of the material world is becoming increasingly historical in character as a result of these new astronomical discoveries. The universe can now be seen as an evolving entity in which necessity, as expressed in the laws of physics, must operate through chance events and cannot determine the movement of matter, even at this macroscopic level, in a purely mechanical way.

[1] <http://www.eso.org/public/news/eso1106/>

[2] The four hundred years of planetary science since Galileo and Kepler, Joseph A. Burns, Nature, Vol 466, 2010.



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