The role of "planet traps" in solar system formation

May 7 2015

A team from the Astrophysics, Instrumentation and Modelling laboratory at Paris-Saclay (AIM – CNRS/CEA/Université Paris Diderot) has developed a new model that represents the evolution of protoplanetary disks over millions of years. These giant structures, composed of dust and gas, are thought to be the ideal place for planet formation due to the presence of what researchers call "planet traps". Scientists have been able to use this new model to detect the most favourable locations for forming planets. The research results will be published on-line in the *Astronomy & Astrophysics* journal on 6 May.

There are planets that exist outside the solar system, known as "exoplanets", that orbit stars other than the sun. Since the first exoplanet was discovered in 1995, scientists have advanced a number of scenarios in their attempts to explain the appearance of these planets around the stars. The most widely-accepted idea points to the existence and role of disks of dust and gas, called protoplanetary disks, within which embryonic planets may develop. If we are to understand the formation of the solar system and exoplanets, the long-term evolution of these disks needs to be modelled. The temperature in the mid-plane of a disk determines its evolution and, by monitoring the composition throughout the disk's development, it becomes possible to ascertain the conditions that promote the formation and growth of planets.

The team from the AIM laboratory has designed a new protoplanetary disk model by coupling calculations on the dynamics, thermodynamics and the geometry of the disks. This means that a disk's evolution can be followed over time and that the migration of the planetary embryos inside it can be analysed. The model has also been used to determine the position of the sublimation lines of the different species of dust in the disk, i.e. the boundary beyond which some of the dust particles change from the solid to the gaseous state.

The researchers were then able to pinpoint the places that are conducive to the survival and growth of "baby" planets by tracking the migration of planetary embryos that might be formed in such disks. These embryos accumulate in areas that will ensure they survive by preventing them from colliding with their star, at the same time as favouring collisions, thus allowing them to grow by accretion. These zones, called "planet traps", are located on the dust sublimation lines. By monitoring the planet traps throughout the evolution of the protoplanetary disk, stable zones can be identified where the planets can survive and grow bigger, and where they can be distinguished from more transient traps that only retain the planetary embryos on a temporary basis.

The researchers have also demonstrated the essential role of the sublimation line of water ice (previously thought to have been abrupt and fine) in forming the planets at the heart of our solar system. Inside this line relatively small planets - such as the earth - are formed, which contain large amounts of silicates and, as a result, higher densities. Outside the ice boundary, on the other hand, where water can be in solid state, giant planets with lower densities - such as Jupiter - occur.

By combining this detailed model of the development of protoplanetary disks with a simulation of the growth of planetary embryos, we will eventually have a better understanding of the composition of the cores of the planets in our solar system. In addition, it is clear that future observations by the ALMA millimetre and submillimetre observatory will help to refine the data that has been collected on the places where exoplanets are formed.

Provided by CEA