The rocks that remained

An alternative model suggests that the asteroid belt originated from leftovers from the formation of the planets in the solar system

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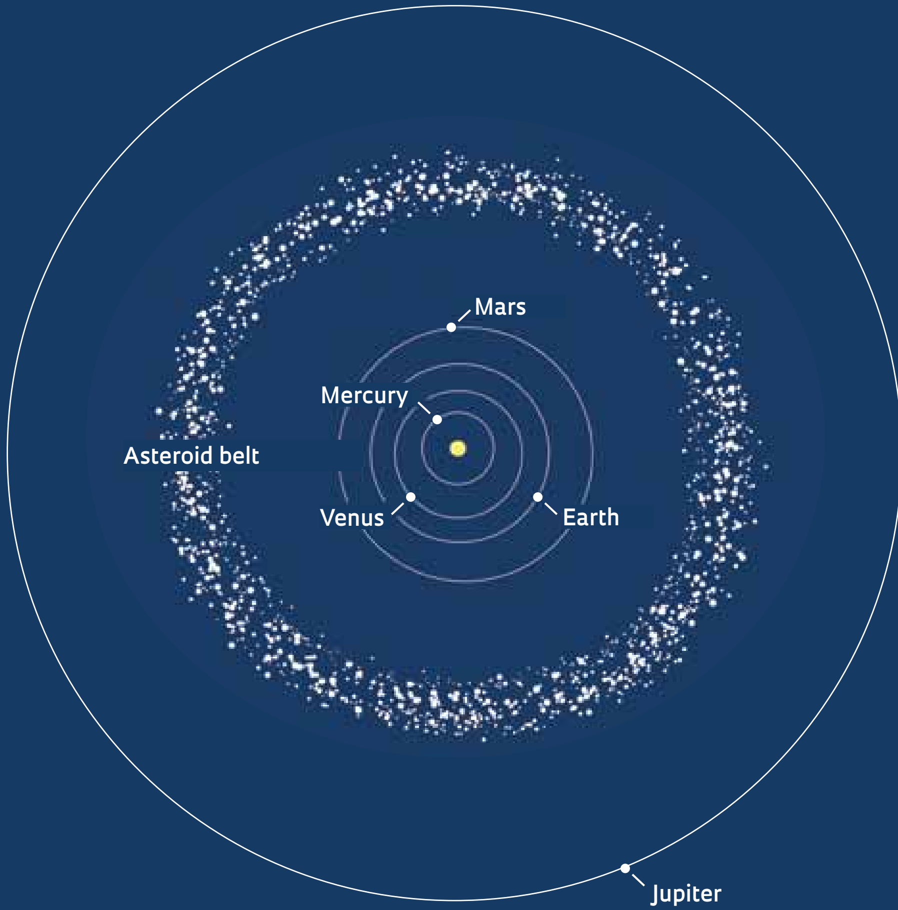
Billions of irregularly shaped masses, most of which are the size of a stone but a few are hundreds of kilometers in diameter, revolve around the Sun in the region between the orbits of Mars (the last of the four rocky planets) and Jupiter, which is the largest planet in our system. This group of orbiting rocks composes what is conventionally known as the asteroid belt. The origin of this agglomeration of asteroids is a mystery; however, it is widely accepted that there was much more of this material in this region in the early days of the solar system and that 99% of it was expelled for some reason. Astrophysicists André Izidoro of the Orbital Dynamics and Planetology Group at São Paulo State University's Guaratinguetá campus and Sean Raymond of the University of Bordeaux in France proposed a new model that is based on computational simulations to explain the origin of the asteroid belt and is in sharp contrast with more traditional ideas. In the September 13 issue of *Science Advances*, these astrophysicists published an article that contained the details of their alternative model.

According to Izidoro and Raymond, the region where the belt is located today had been a large void when the solar system was born approximately 4.5 billion years ago, rather than a place where matter was concentrated, as other better-known models have maintained. In this model, the current configuration of the belt is not the result of enormous losses of matter throughout the history of the system but rather a modest gain in matter. "The most external portion of the asteroid belt originated as a byproduct of the formation of the solid nucleus of the gas giant planets, namely, Jupiter and Saturn," explains Izidoro. "And the innermost part emerged from the residues of planetary embryos that were the origins of the terrestrial planets, namely, Mercury, Venus, Earth and Mars." According to this hypothesis, agglomerations of materials that were not part of the composition of the gaseous or the terrestrial planets, particularly Jupiter and Mars, were expelled to the area where the solar system would arise, which at that time was empty due to gravitational interactions and the dragging action of gas that was present in space. This phenomenon led to the asteroid belt. This area, which is filled with stones of various

The asteroids 433 Eros (*left*) and 253 Mathilde: 433 Eros is an S-type asteroid, rich in silica and typical of the interior of the belt; 253 Mathilde is a C-type asteroid containing carbon, more commonly found in the outer portion

From nothing to the belt

According to a model that was proposed by astrophysicists from Brazil and France, the inner part of the belt was formed mostly from matter that was left over from the formation of the rocky planets, especially Mars. Most asteroids in the outermost portion of the belt originated from what remained after the process of forming Jupiter



SOURCE ANDRÉ IZIDORO AND SEAN RAYMOND

sizes, is described by Raymond as a "cosmic refugee camp".

The new model also explains the arrangement of the two main types of asteroids within the belt. The area that is farthest from the Sun is where C-type asteroids concentrate; they are dark and rich in carbon and comprise 75% of the objects in the belt. Within the more internal section, most objects are S-type asteroids, which are brighter, have a high concentration of silica, and account for 17% of the belt's bodies. According to Izidoro and Raymond's model, C-type asteroids (which are also called wet asteroids) originated from material that remained after the formation of gas giant planets. "Water on Earth may also have come from these asteroids that eventually collided with our planet when it was still forming," says Izidoro, who, together with Raymond, addressed this issue in another recent article that was published on June 30 in the scientific journal *Icarus*. S-type asteroids, which are considered dry, are what remains of the materials that were used in the formation of Mars and other terrestrial planets.

For months, Izidoro and Raymond ran more than 200 computer simulations to determine how the planets in the solar system may have formed and how the asteroid belt consequently emerged. The simulations assumed that no primal material was present between Mars and Jupiter and the researchers were able to virtually reproduce the current constitution of the belt. "Our next step is to test how each of the existing models, including our own, explain the asteroid belt and determine what we can learn about the formation of the solar system," says Raymond.

LOW DENSITY

For astrophysicist Jorge Meléndez of the Institute of Astronomy, Geophysics, and Atmospheric Sciences at the University of São Paulo (IAG-USP), the simulations by Raymond and Izidoro are very interesting and provide a new vision of the solar system. "The study shows that at the beginning of the system, a much more massive asteroid belt was not necessary," says Meléndez. "One of the problems with the current model is explaining how this belt [which was supposedly very large early in its development] lost so much mass." Currently, the mass of the belt is no more than 4% that of the Moon and is more than a thousand times less than that of the Earth. Although the asteroids within it spin around an enormous swath of the solar system, the belt itself has a low density of objects in relation to its area. A single celestial body, namely, the dwarf planet Ceres, has the same mass as one third of the entire asteroid belt. ■

Project

Planetary formation and dynamics: From the solar system to exoplanets (No. 16/12686-2); **Grant Mechanism** Junior Researcher; **Principal Investigator** André Izidoro (UNESP); **Investment** R$178,755.00.

Scientific articles

RAYMOND, S. N. and IZIDORO, A. The empty primordial asteroid belt. **Science Advances**. September 13. 2017.

RAYMOND, S. N. and IZIDORO, A. Origin of water in the inner Solar System: Planetesimals scattered inward during Jupiter and Saturn's rapid gas accretion. **Icarus**. June 30. 2017.