Calculating the complex behaviours of multi-body asteroids

In the earliest days of the solar system, the sun was orbited by a uniform disk of gas and dust. Over time, some of this material collapsed under its own gravity to eventually form smooth, spherical bodies – which we now call planets. However, this doesn’t tell the whole story. Vast amounts of interplanetary gas and dust never coalesced into planets; much of what was left came to form smaller, irregularly shaped bodies, named asteroids. Each under 1,000 kilometres in diameter, asteroids encompass a diverse range of shapes, sizes, and compositions, and can also display intriguing orbital behaviours.

Until recently, astronomers have only been able to observe systems of individual asteroids, but now they are aware that smaller rocks, named ‘moonlets’, can orbit around larger asteroids, named ‘primaries’. “Discovered by Galileo spacecraft in 1993, Ida and its orbiting moonlet, Dactyl, is the first binary asteroid system ever found in the Solar system,” explains Dr Jiang. “Since then, several binary asteroid systems have been discovered in the solar system. In 2004, the first triple asteroid system was found, named 87 Sylvia, it has two moonlets: Romulus and Remus. As of June 2019, 341 binary asteroid systems and 75 triple systems have been found.” In his research, Dr Jiang studies the diverse behaviours which unfold within these complex systems, with the aim of discovering more about how the solar system has transformed since its earliest days.

**STUDYING DYNAMICAL ENVIRONMENTS**

Since asteroids are so much smaller than planets, their gravitational fields are far weaker, which means that unlike planets, most of them cannot collapse to form uniform spheres. If a person were to walk across the surface of an asteroid, therefore, the gravitational force they would experience would vary extremely widely – wholly unlike the uniform force which we are used to on Earth. Because asteroids have likely played a hugely significant role in forming the planets of the solar system as we know them today, Dr Jiang argues that it is important for astronomers to study these complex gravitational behaviours. “Generally, asteroids have irregular shapes which may vary over millions of years, meaning the dynamical behaviours in their gravitational fields are quite complicated,” he says. “The study of asteroids may help us to understand the formation and evolution of the solar system. My interest focuses on the dynamical environment of binary and triple systems.”

As well as studying the movements of asteroids and moonlets, Dr Jiang also analyses the behaviours which arise as they collide with other bodies, causing them to partially disintegrate. “In addition, grains may be generated from the impact of the cosmic debris to the primary or moonlet of a binary or triple asteroid system,” he continues. “These grains may move to planets or other asteroids. If the grains enter Earth’s atmosphere, people will see a beautiful meteor shower.” Currently, Dr Jiang is paying particular attention to these behaviours for two complex multi-body asteroid systems.

**SHAPE VARIATION IN A BINARY SYSTEM**

In the wide gap between Mars and Jupiter sits the asteroid belt: a vast ring of interplanetary rocks which were never able to collapse to form their own planet. Among these asteroids is a system named 41 Daphne, which was discovered in 1856. At first, astronomers thought that Daphne sat by itself, but further observations carried out in 2008 revealed that a far smaller rock was actually in orbit around it, named Peneius. Since this discovery, Dr Jiang has analysed this intriguing system in detail. “Recently, I have studied the dynamical environment in the vicinity of the binary asteroid system 41 Daphne,” he explains. “Daphne is a big asteroid in the main belt; its major axis is larger than 200 kilometres. The moonlet of Daphne, Peneius, has a diameter smaller than 2 kilometres. The separation between mass centres of Daphne and Peneius is about 443 kilometres.”

In planet-moon systems, the interaction of the gravitational fields of the two bodies creates certain ‘equilibrium’ points. These are so-called because, were a small body placed on this point, it would not fall towards either body. Astronomers currently believe that Daphne is irregular in shape, giving it a complex gravitational field, which could host equilibrium points...
**Research Objectives**

Dr Jiang’s work explores the dynamical environment of binary and triple asteroid systems.

**References**


**Personal Response**

What fascinates you most about these binary and triple asteroid systems?

The generation and evolution of dust and debris in the binary and triple asteroid systems.

Dr Jiang’s work explores the dynamical environment of binary and triple asteroid systems.

**DUST GRAIN GENERATION IN A TRIPLE SYSTEM**

Next, Dr Jiang looked at an even more complex system, 87 Sylvia. Discovered in 1866, Sylvia was again first thought to be on its own, but subsequent observations in 2001 and 2004 revealed that two moonlets were actually in orbit around it. “I have also studied the dynamical environment of the triple asteroid system, 87 Sylvia,” describes Dr Jiang. “The mean diameter of Sylvia is about 280 km, the two moonlets, Remus and Romulus, have mean diameters of around 7 km and 18 km, respectively. The separation between the mass centre of Sylvia and its two moonlets is about 707 km and 1357 km.” To investigate the dynamics of this system, Dr Jiang again used computer models to map its gravitational environment, taking account of Sylvia’s irregular shape. In particular, he used his models to simulate the behaviours of small grains of rock, which are thrown up as external debris collides with the system.

Depending on where this debris hits, these grains could follow a variety of different paths; impacting the subsequent behaviour of the system as a whole. “I investigated the motion of the grains generated in different parts of Sylvia,” Dr Jiang explains. “I have now found that some of the grains may impact on the surface of the primary, which may produce more grains; and some of the grains may escape the triple system and enter interplanetary space.” Such grains were likely to be in orbit around the sun long before any planets, or even asteroids, had had the time to form. Therefore, studying them in more detail can tell us more about how the solar system as we know it today came into being.

**NEW INSIGHTS INTO FORMATION AND EVOLUTION**

In the future, some astronomers are strongly hoping that a spacecraft will be sent to the asteroid belt to investigate the dynamics of a double or triple system, like Daphne or Sylvia, in unprecedented levels of detail. For such a mission to succeed, Dr Jiang’s calculations will prove critical to designing the trajectories of the spacecraft, to ensure it can safely arrive at such incredibly small, yet complex targets. The insights provided by these potential missions could one day prove invaluable to researchers in a wide variety of fields, potentially answering long-standing questions about how our solar system first formed, and how it evolved over time.