

## Earth & Space

# The first interstellar immigrant of the solar system

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### ABSTRACT

*The asteroids and comets of the solar system did not all form in situ as some were captured during the late stages of planet formation. Identifying asteroids that "immigrated" to the solar system from other star systems has now become possible.*



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Our solar system did not form in isolation from the rest of the Galaxy. It was part of a star cluster where each member has its own planets and asteroids. The close proximity of the cluster members favored strong gravitational interactions that pulled asteroids and sometimes planets from a star system to another leading to the phenomenon of interstellar immigration. Some of the bodies present in the solar system on stable orbits around the sun must therefore have come from other star systems but no asteroid or comet has so far been identified as an interstellar immigrant until the discovery of asteroid (514107) 2015 BZ509, BZ for short.

First observed in Hawaii in late 2014, BZ was found to be travelling around the sun in the opposite direction to Jupiter and all planets. BZ has a special gravitational relation with Jupiter known as

resonance that makes the asteroid travel around the sun in about 12 years, the same time as Jupiter's motion. BZ's orbit is inclined by 17 degrees with respect to Jupiter's precluding the possibility of catastrophic collisions. Objects that travel around the sun in the opposite direction to all planets are not unheard of. A good example is the famous Halley's comet. Such retrograde motion, as it is called, usually indicates that the object originated in the [Oort cloud](#), a comet reservoir located in the farthest region of the solar system where the sun's gravitational attraction is so weak that the influence of its neighboring stars in the Galaxy is enough to flip an asteroid's or a comet's orbit. Asteroids and comets with retrograde motion may venture towards the planets' domain, wander between the various planets never sticking near one for more than a few thousand years, to finally leave the

planets' domain after a few million years. Such objects are called retrograde Centaurs.

When BZ's motion was identified, the asteroid was thought to be a retrograde Centaur that came from the Oort cloud. However, computer simulation of its orbit showed that it lived near Jupiter for at least a million years. This hinted to a different origin than most Centaurs. Following the asteroid back in time for much longer was not possible because of the chaotic nature of its motion. Commonly illustrated by the butterfly effect, that small changes lead to large and potentially catastrophic consequences, chaos in an asteroid's motion is simpler to grasp: small errors in an asteroid's current position lead to completely different positions in the past. This seems to preclude ever identifying where an asteroid came from as astronomical observations can never achieve infinite precision. To overcome the chaos hurdle, BZ's orbit was replicated a million times into a clone cluster that covers with great precision the known observational error of BZ's orbit. The clones' motion was simulated with intensive computing over the past 4.5 billion years to the time where the solar system's planets finished forming. Surprisingly, most BZ clones clustered around its current retrograde orbit near Jupiter and only a few were found in the Oort cloud region. However, at that epoch, all solar system planets, asteroids and comets went around the sun in the same direction. Furthermore, current

planet formation theories show that the Oort cloud region did not contain any material from the solar system 4.5 billion years in the past as the planets did not have enough time to scatter asteroids and comets to that distant location. There are therefore two possibilities for BZ's origin. The likelier is that BZ was captured near Jupiter directly from the interstellar medium whereas the less likely is that it came from the Oort cloud region that, if not empty, must have been full of asteroids captured from the solar system's star cluster. Either way, BZ is of interstellar origin.

Beyond establishing the phenomenon of interstellar immigration as a reality, the discovery BZ's extrasolar origin has important consequences. First, the application of the million clone simulation to other solar system asteroids will produce a portrait of the solar system's small body reservoirs 4.5 billion years ago. This will better constrain planet formation theory and identify the possible locations of captured interstellar asteroids and comets. Second, the study of BZ's chemical composition by ground-based telescopes and possibly dedicated space probes will provide further information on the role of such extrasolar objects in the enrichment of the solar system's planets particularly regarding the still-mysterious problem of the origin of water on Earth.