Jupiter and the theory of relativity blamed for course changes of celestial bodies

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The famous Barringer meteor crater in Arizona, which was created by an impact about 50 000 years ago. Credit: D. Roddy, Lunar Planetary Institute, NASA

In the case of solar system bodies passing close to the sun, there are two important effects playing a crucial role in the orbital evolution. One of the effects is from the general relativity and the other effect is from Newtonian theory of gravitation.

The prediction of a periodic shift in the orbit (which is technically called precession in celestial mechanics) of Mercury and the subsequent confirmation of this additional shift in orbit from real observations, was one of the greatest triumphs of general relativity developed by Einstein about 102 years ago.

This is one of the important effects which occur in solar system bodies passing close to the sun because orbital velocities increase considerably when bodies come near the sun and when the velocities increase substantially, relativistic effects can become important (Figure 1).

The other effect is from the periodic gravitational influences of Jupiter (technically called the Kozai mechanism in celestial mechanics) from the Newtonian theory which make the orbit narrower and narrower (or in other words, more and more elliptical) and make the orbiting body come closer and closer to the sun after every subsequent revolution.

These gradual gravitational effects from Jupiter have led to the production of some exceptionally spectacular sungrazing comets (i.e. comets which come very close to the sun and hence very bright in appearance from our planet) in Earth's history.

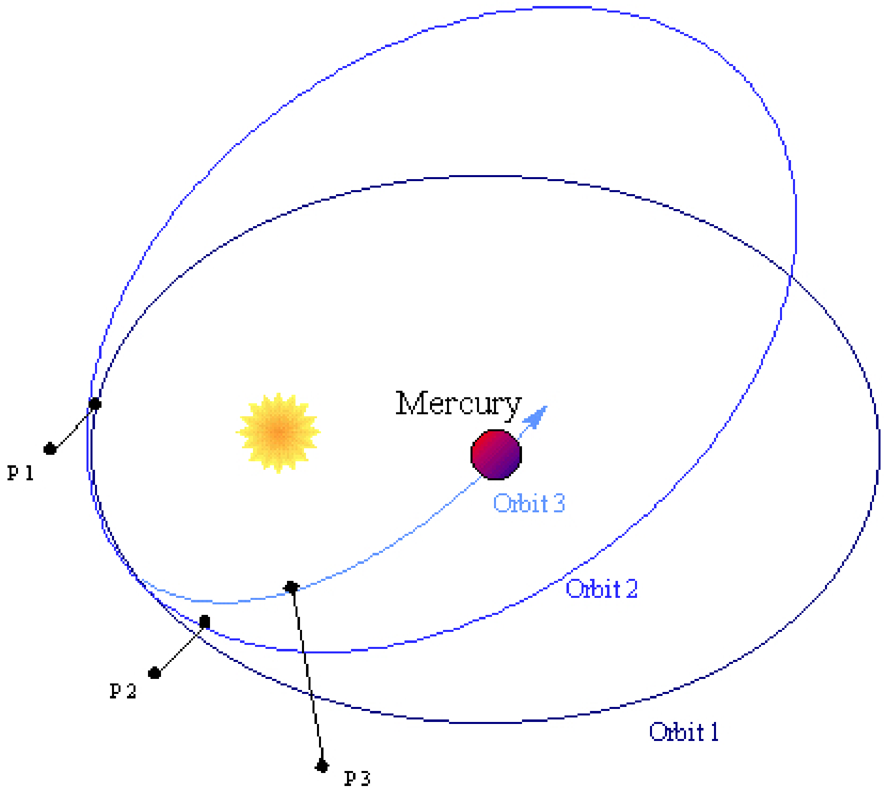

Figure 1. Simple schematic of the shift of orbit of planet Mercury due to general relativistic effects; the orbit itself rotates slowly. Credit: Cornell University

Previous works in solar system science have looked into these effects separately for some bodies, but in our present study, we look at the interesting scenarios when we have the combination of both these effects in solar system bodies.

Our calculations show that these periodic gravitational influences from Jupiter can lead to rapid enhancements in orbital shifts due to general relativity by virtue of the bodies coming closer to the sun after every passage around the sun. Sometimes the bodies can have extreme close approaches to the sun which eventually lead to collision with the sun, induced by these periodic effects from Jupiter.

A good example which shows this property in our studies is comet 96P/Machholz 1 which undergoes rapid sun approaching phases and eventually falls into the sun in about 9,000 years from present time.

Figure 2. Map of known craters found on Earth due to impacts of bodies from space. Credit: Stephanie Werner

During its final journey just before the collision with sun, we find that the orbital shifts due to general relativity can peak to about 60 times that of the orbital shift of Mercury, which is a record high value in the context of solar system bodies observed so far.

Furthermore this comet undergoes a reversal in its reference orbital direction (technically called an inclination flip in celestial mechanics) due to Jupiter's systematic gravitational effects.

Our study shows for the first time an example of a solar system body which shows all these previously mentioned effects and traits overlapping in a neat way. This makes this study new and unique from previous orbit studies of similar solar system objects.

The comet C/1965 S1 (Ikeya-Seki) was one of the most spectacular sungrazing comets in history. Credit: Maynard Pittendreigh

Moreover we find that the combination of both above-said effects have important consequences in the realm of impact studies on Earth from small solar system bodies. Our calculations show that even a small orbital shift due to general relativity can vary greatly the closest orbit distance between the solar system body and Earth.

Jupiter's periodic effects can enhance the general relativistic effects in some solar system orbits. This leads to close approach scenarios between solar system bodies changing significantly.

This in turn plays an important role in studying and assessing long term impact threat estimates on Earth, which can create interesting and remarkable features like craters and meteor storms on our Earth.

Our planet has been bombarded with different solar system bodies of different sizes throughout its orbital history (Figure 2) and these signatures in the form of craters act as a crucial tool to understand the evolution and dynamics of our Earth (which is the focus theme of CEED based at UiO).

The Pan-STARRS PS1 telescope on Hawaii is currently the most active hunter for Near Earth Objects. Credit: Institute for Astronomy, University of Hawaii

The modern telescopic surveys are scanning the sky continuously to find solar system objects which could potentially come very close to the Earth and become a threat for our Earth in future.

Today's precise observations aided by large telescopes in different parts of the world and detailed theoretical calculations augmented by supercomputing facilities (like USIT NOTUR computing clusters) aim to come up with better models in the context of short term and long term impact hazard studies to make Earth a safer place in the larger picture of our existence.

More information: A. Sekhar et al. Change in general relativistic precession rates due to Lidov–Kozai oscillations in Solar system, *Monthly Notices of the Royal Astronomical Society* (2017). DOI: 10.1093/mnras/stx548

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