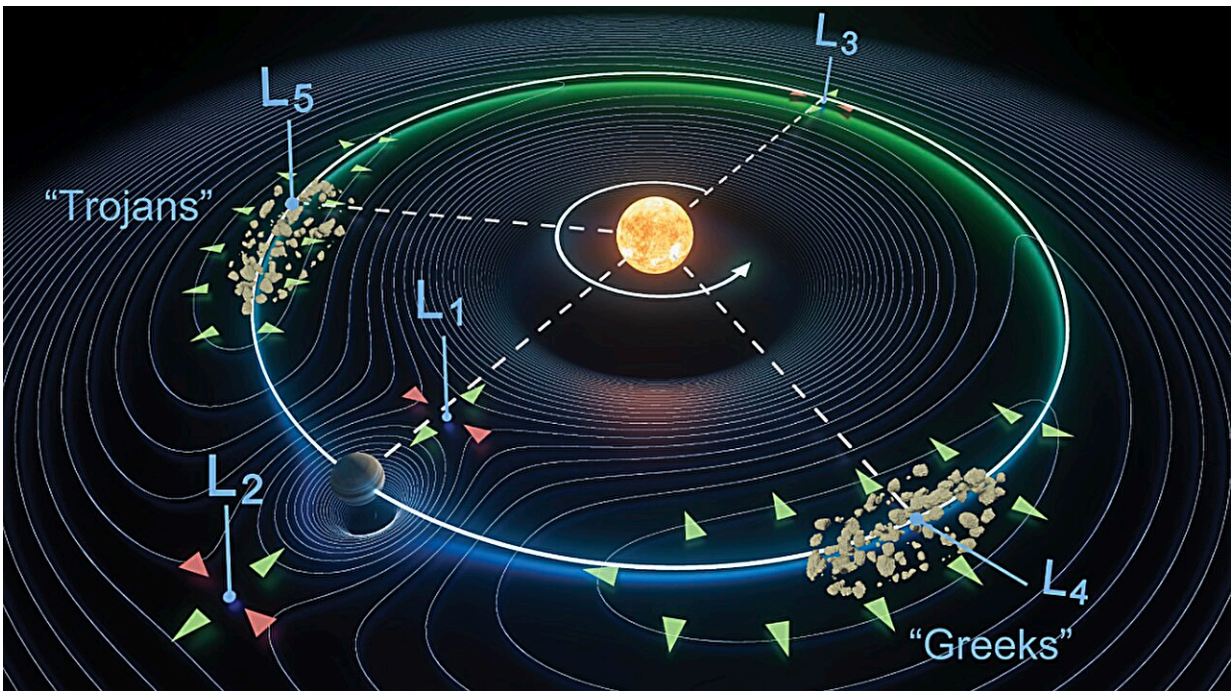


# A Trojan approach to guide and trap light beams via Lagrange points

January 30 2024, by Ingrid Fadelli



Celestial dynamics in the vicinity of a stable Lagrange point. Lagrange points in the sun-Jupiter system. In the co-rotating frame, the potentials associated with the three unstable colinear Lagrange points ( $L_1$ ,  $L_2$  and  $L_3$ ) are saddle-shaped while those of  $L_4$  and  $L_5$  are stable, being maxima. The "Greek" and "Trojan" asteroid groups are captured around  $L_4$  and  $L_5$ , respectively. Credit: Luo et al

Reliably guiding and capturing optical waves is central to the functioning of various contemporary technologies, including communication and

information processing systems. The most conventional approach to guide light waves leverages the total internal reflection of optical fibers and other similar structures, yet recently physicists have been exploring the potential of techniques based on other physical mechanisms.

Researchers at University of Southern California recently devised a highly innovative approach for trapping light. This method, [introduced](#) in *Nature Physics*, exploits the exotic properties of Lagrange points, the same equilibrium points that govern the orbits of primordial celestial bodies, such as so-called Trojan asteroids in the sun-Jupiter system.

"The discovery of Lagrange points, which happens to be pivotal in this research, can be traced back to the early work of Leonhard Euler and Joseph-Louis Lagrange, which found that at these locations, the [gravitational attraction](#) exerted by two large bodies can be precisely counterbalanced by centrifugal forces," Mercedeh Khajavikhan and Demetrios N. Christodoulides, co-authors of the paper, told Phys.org.

"While some of these points, notably and, are already employed as strategic positions in space for satellite stability with minimal propellant consumption (as exemplified by the James Webb telescope and the recently deployed Aditya L1 satellite), our study focuses on the intriguing properties of and Lagrange points."

Trojan asteroids are a large group of asteroids circling the sun on the same orbit as the planet Jupiter. Lagrange points, named after the renowned mathematician Lagrange who uncovered them, are positions in space in which the gravitational force of two bodies in the same system (e.g., the sun and Jupiter) produce enhanced regions of attraction and repulsion.

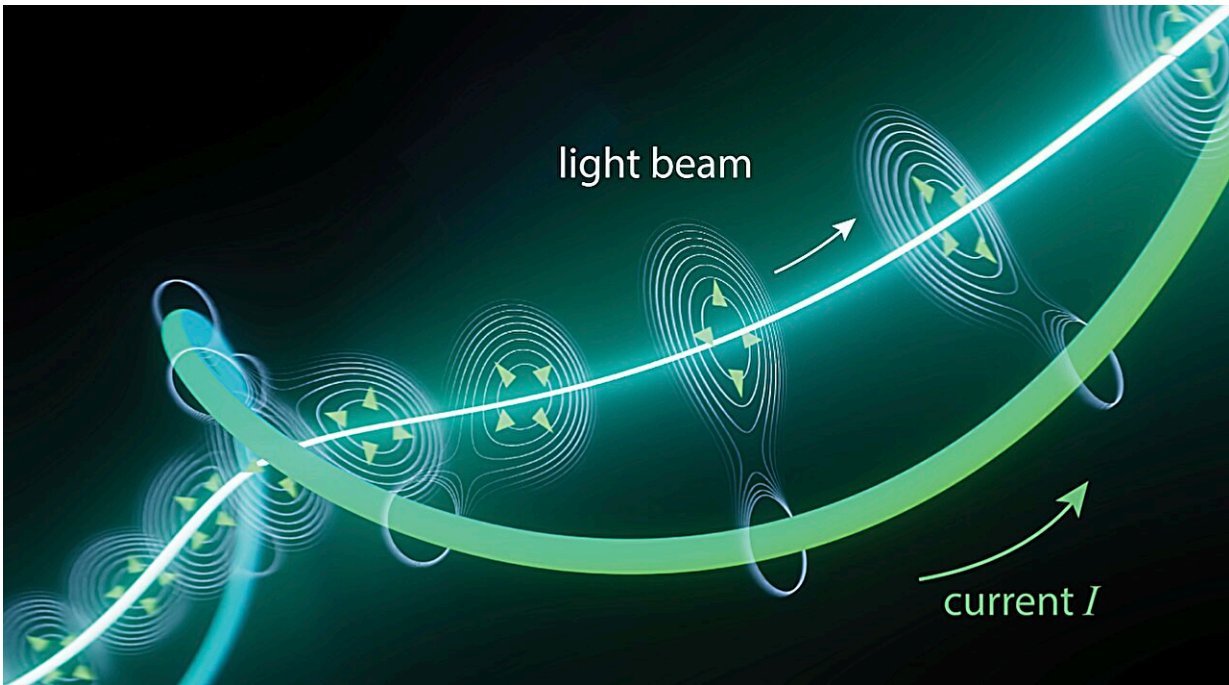
As part of their study, Khajavikhan and Christodoulides set out to investigate the potential of utilizing the unique physics of these positions

to guide and trap light waves. In their paper, the researchers showed that the use of and Lagrange points for optical applications in some ways resembles capturing Trojan asteroids within the sun-Jupiter orbit.

"The Lagrange [optical waveguide](#) is induced by passing current through a helical wire in a cured silicon oil cylinder," Khajavikhan and Christodoulides said.

"By means of the thermo-optic effect, this in turn produces a twisted index landscape where in this case, the photon repulsion is balanced by the centrifugal force. Counterintuitively, in this mountain-slope index profile, a stable Lagrange point, is produced and as a result, a Trojan optical beam is trapped in a two-dimensional fashion at this position."

As part of their study, Khajavikhan and Christodoulides created a compact system in their laboratory reproducing the properties of Lagrange points, such as those observed in the orbits of Trojan asteroids. Their laboratory-built system was comprised of a helically-shaped iron wire inserted in a medium with a temperature-dependent refractive index.



Credit: Luo et al.

The researchers could later heat this medium in a non-homogeneous way by passing electricity through the wire. Ultimately, this process enabled the formation of what they refer to as a Trojan optical beam.

This simple experiment led to very interesting observations. Interestingly, the researchers found that optical Trojan beams could be guided or captured in this defocusing refractive index environment, something that is not feasible under normal circumstances.

"More importantly, the refractive index landscape where these optical beams are captured is completely unremarkable, having no features whatsoever that could foretell a guiding response," Khajavikhan and Christodoulides said. "In essence, the optical beam is trapped in a nowhere land—in completely inconspicuous regions where no

conventional waveguide structures exist."

The recent work by this team of researchers shows the unique characteristics of Lagrange points can be leveraged to guide and trap light waves. In the future, it could form the development of new techniques to guide [optical waves](#) in unconventional environments when conventional approaches are ineffective, such as in liquids and gases.

"A possible avenue for further exploration could be the use of Trojan beams in amplifying (laser) systems, where optical gain or loss can establish alternative means for [beam](#) attraction or repulsion in fully dielectric media," Khajavikhan and Christodoulides said.

So far, the researchers have only focused on the use of Lagrange points for guiding light beams. However, in the future the methodology they developed could also be tested in other areas of physics reaching beyond optics, for instance as a technique to guide acoustic waves or ultracold atoms.

"At this point, we plan to explore the possibility of guiding light in acoustic waves in both liquid and gaseous media," Khajavikhan and Christodoulides added. "Finally, of interest would be to observe for the first-time trapping and transporting dielectric micro- and nano-particles in Lagrange waveguides using optical tractor beams where multiple Lagrange points can be induced—an aspect that is not possible in celestial mechanics."

**More information:** Haokun Luo et al, Guiding Trojan light beams via Lagrange points, *Nature Physics* (2024). [DOI: 10.1038/s41567-023-02270-6](#)

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