ICE & STONE 2020

WEEK 42: OCTOBER 11-17

Presented by The Earthrise Institute

Authored by Alan Hale

THIS WEEK IN HISTORY

OCTOBER 11 12 13 14 15 16 17

OCTOBER 11, 1983: The InfraRed Astronomical Satellite (IRAS) spacecraft discovers the "asteroid" now known as (3200) Phaethon. Phaethon had the smallest perihelion distance of any asteroid known at the time, and was soon found to be traveling in the same orbit as the Geminid meteors, suggesting it may be their parent object and thus may also be a defunct comet. Since then it has occasionally exhibited small bursts of cometary activity when near perihelion. The linkage between comets and meteor showers, and cometary activity within asteroids, are subjects of future "Special Topics" presentations.

11 OCTOBER 12 13 14 15 16 17

OCTOBER 12, 1892: American astronomer Edward Barnard at Lick Observatory in California takes a 4-hour-long exposure of a Milky Way star field, and later notices the trail of a 12th-magnitude comet on the resulting photograph; this would be the first comet ever discovered via photography. Barnard's comet was found to be periodic, but was lost until rediscovered by Andrea Boattini with the Catalina Sky Survey in 2008; it is now known as Comet 206P/Barnard-Boattini.

OCTOBER 12, 1950: At a meeting of the National Academy of Sciences, American planetary scientist Gerard Kuiper proposes the existence of a population of "protocomets" in the solar system beyond Neptune; the paper was published the following year. The idea of a "Kuiper Belt" lay dormant for the next three decades before being revived in 1980 by Uruguayan astronomer Julio Fernandez, and its existence was confirmed a little over a decade later. The Kuiper Belt is the subject of a previous "Special Topics" presentation.

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OCTOBER 13, 902: Observers in Europe, Egypt, and elsewhere see a strong meteor "storm," wherein "stars fell like rain," appearing to come from the constellation Leo. This is the first recorded incident of the Leonid meteor shower, which has produced equally strong "storms" on subsequent occasions. The Leonids are associated with Comet 55P/Tempel-Tuttle, and the link beyond comets and meteor showers is the subject of a future "Special Topics" presentation.

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OCTOBER 15, 2003: The LONEOS program in Arizona discovers a fast-moving asteroid which is soon found to be identical to the long-lost asteroid Hermes, which had passed extremely close to Earth in 1937 but only followed for four days. Hermes has now been numbered (69230), and it is discussed in the Week 2 "Special Topics" presentation.

OCTOBER 15, 2014: Scientists associated with NASA's MESSENGER mission report that MESSENGER has imaged water ice in the crater Prokofiev near Mercury's north pole. Water ice in Mercury's polar regions had been suspected in radar data as early as 1991 and confirmed by MESSENGER data in 2012, but this was the first report of direct images of such ice. The existence and significance of water ice on Mercury is discussed in a previous "Special Topics" presentation.

OCTOBER 15, 2015: A team of scientists led by Tabetha Boyajian (then at Yale University) and which included "citizen scientists" announces their discovery that, in data taken with the Kepler Space Telescope, the 12th-magnitude star KIC 8462852 – now informally referred to as "Boyajian's Star" – has been undergoing large and irregular drops in brightness. One of the potential explanations for these brightness drops is an orbiting swarm of "exocomets," and this is discussed in a previous "Special Topics" presentation.

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OCTOBER 16, 1982: CalTech graduate student David Jewitt and Palomar Observatory staff astronomer G. Edward Danielson recover Comet 1P/Halley on its 1986 return with a CCD attached to the 5.1-meter Hale Telescope at Palomar. This was the first time that a CCD had been used to recover a comet. Comet Halley, then at a heliocentric distance of just over 11 AU, was a little less than 3½ years away from perihelion at the time and appeared as a stellar 24th-magnitude object. The 1986 return of Comet Halley is a previous "Comet of the Week."

11 12 13 14 15 16 OCTOBER 17

OCTOBER 17, 1906: August Kopff at Heidelberg Observatory in Germany discovers the asteroid now known as (617) Patroclus. Patroclus, now known to have a binary companion, was the second "Jupiter Trojan" asteroid to be discovered, and is scheduled to be visited by NASA's Lucy mission in 2033. Lucy is discussed in a previous "Special Topics" presentation, and Trojan asteroids are the subject of this week's "Special Topics" presentation.

OCTOBER 17, 1983: A team led by Fred Gillett and Hartmut Aumann announces that the bright star Vega exhibits a strong excess of infrared emission in data taken by the InfraRed Astronomical Satellite (IRAS) spacecraft, indicating that it is accompanied by a disk of dusty material. Subsequent studies of the Vega dust disk suggest that it may primarily be the result of collisions between bodies – as is much of the dust in our solar system – but some of it may be the remnant of a planet-forming disk. These disks and the process of planet formation are the subjects of a future "Special Topics" presentation.

OCTOBER 17, 2020: The main-belt asteroid (45666) 2000 EX91 will occult the 6th-magnitude star 52 Orionis. The predicted path of the occultation crosses southern Greenland, northeastern Iceland, central Europe including northeastern Germany, far western Czech Republic, eastern Austria, eastern Slovenia, central Croatia, central Bosnia-Herzegovina, central Montenegro, central Albania (just east of Tirana), western Greece, and far western Crete; and north-central Africa including west-central Egypt, northeastern Sudan (just east of Khartoum), western Ethiopia, east-central Kenya, and central Madagascar.

COMET OF THE WEEK: THE GREAT COMET OF 1811

Perihelion: 1811 September 12.76, q = 1.035 AU

Once the orbital calculations for Comet Hale-Bopp C/1995 O1 were made and it appeared that it would be making a "Great Comet" display a year and a half in the future, it was natural for those of us at the time to search for historical analogs. A very good historical analog was the Great Comet of 1811, which – although there is clearly no relationship between the two objects – shares several characteristics with Hale-Bopp, including a high intrinsic brightness, a moderately large perihelion distance, and a rather far distance from Earth. Both comets were visible for a long period of time and both of them were among the brightest and most-observed comets of their respective timeframes.

The Great Comet of 1811 over the Katz Castle in the German town of St. Goarshausen in what is now Rhineland-Palatinate.

Although it was never formally named for him, the Great Comet of 1811 was discovered by a French astronomer, Honore Flaugergues, on the evening of March 25 of that year. At that time it was somewhat deep in the southern sky at a declination of -30 degrees in what is now the constellation Puppis, and although located at a heliocentric distance of 2.72 AU and almost six months away from perihelion passage it was already close to naked-eye visibility. By the latter part of May it had brightened to 5th magnitude, although it was also starting to get low in the southwest after dusk, and the last observations before conjunction with the sun were obtained around the middle of June.

After being hidden in sunlight for two months the comet began emerging into twilight around mid-August, already as bright as 2nd or 3rd magnitude. It continued moving northward from that point, and by early September was easily visible from throughout the northern hemisphere as a bright object of 1st or 2nd magnitude with a tail well over ten degrees long.

The comet was at its best during early October, when it was a spectacular object high in the northwestern evening sky located south and east of the "handle" of the Big Dipper, as bright as magnitude 1 or 0 with a bright dust tail 25 degrees long or longer. It was closest to Earth on October 16, still at a relatively distant 1.22 AU, and displayed a coma half a degree in diameter – indicating a physical size larger than the sun. It began a slow fading after that as it traveled southward, although the tail remained moderately long and conspicuous for some time thereafter, and even in December the comet was still 3rd to 4th magnitude and exhibiting a 5-degree-long tail.

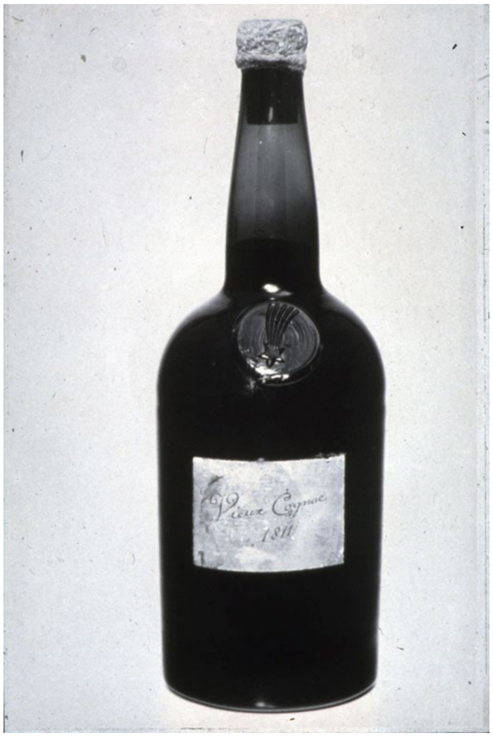
In early January 1812 the comet was still as bright as 5th magnitude, although by this time it was starting to get low in evening twilight, and it disappeared into the dusk by the middle of that month. After being in conjunction with the sun in mid-February it began emerging into the morning sky towards the end of March, although there are apparently no recorded observations of it until July. The astronomers of the time thereafter followed it until mid-August, with the last recorded observation being made on August 17, by which time it had faded to 11th magnitude and its heliocentric distance was 4.54 AU. Overall, the comet's period of visibility of almost 17 months was a record for the time, and the 8½ months of naked-eye visibility was a record which stood until Comet Hale-

Bopp came along almost two centuries later.

The bright and long-lasting appearance of the Great Comet of 1811 seems to have had a profound effect on the non-astronomers of the time. Like other bright comets of the past, it was associated with – perhaps even said to have "predicted" – some of the major historical events that occurred then, such as the series of New Madrid earthquakes that occurred in what is now Missouri in the U.S. during late 1811 and early 1812, as well as wars such as the U.S. War of 1812 and Napoleon Bonaparte's invasion of Russia that same year; indeed, in some quarters it was apparently even referred to as "Napoleon's Comet." At one point in his novel "War and Peace" – which centers to some extent on Napoleon's invasion of Russia – Leo Tolstoy has his character Pierre Buzukhov observing this "enormous and brilliant comet," and this incident is also featured in the 2012 musical production "Natasha, Pierre & The Great Comet of 1812" which is based upon this segment of "War and Peace." Among other references to the comet in the literature and art of the time, it is apparently featured in the British artist William Blake's painting "The Ghost of a Flea."

The Great Comet of 1811 on October 15, 1811, from Otterbourne Hill near Winchester, England.

The port wine vintage from Portugal and France seems to have been exceptionally good in 1811, and while there is clearly no causal relationship between that and the Great Comet of 1811, the winemakers and merchants of the time realized a good marketing opportunity when they saw one, and "Comet Wine" was sold at high prices for many years thereafter. Like the comet itself, "Comet Wine" from 1811 has also been featured as minor – and sometimes even major – plot elements in several stories, including Ernst Junger's 1939 novel "On the Marble Cliffs;" one of Arthur Conan Doyle's Sherlock Holmes stories ("The Adventure of the Stockbroker's Clerk"); in one of the stories in the 1986 Isaac Asimov, et al. "Comets" anthology mentioned in a previous "Special Topics" presentation; and even in the 1992 movie "Year of the Comet." At least one bottle of "Comet Wine" was not opened and tasted until 1996, and in the meantime I am not aware if any other unopened bottles remain.

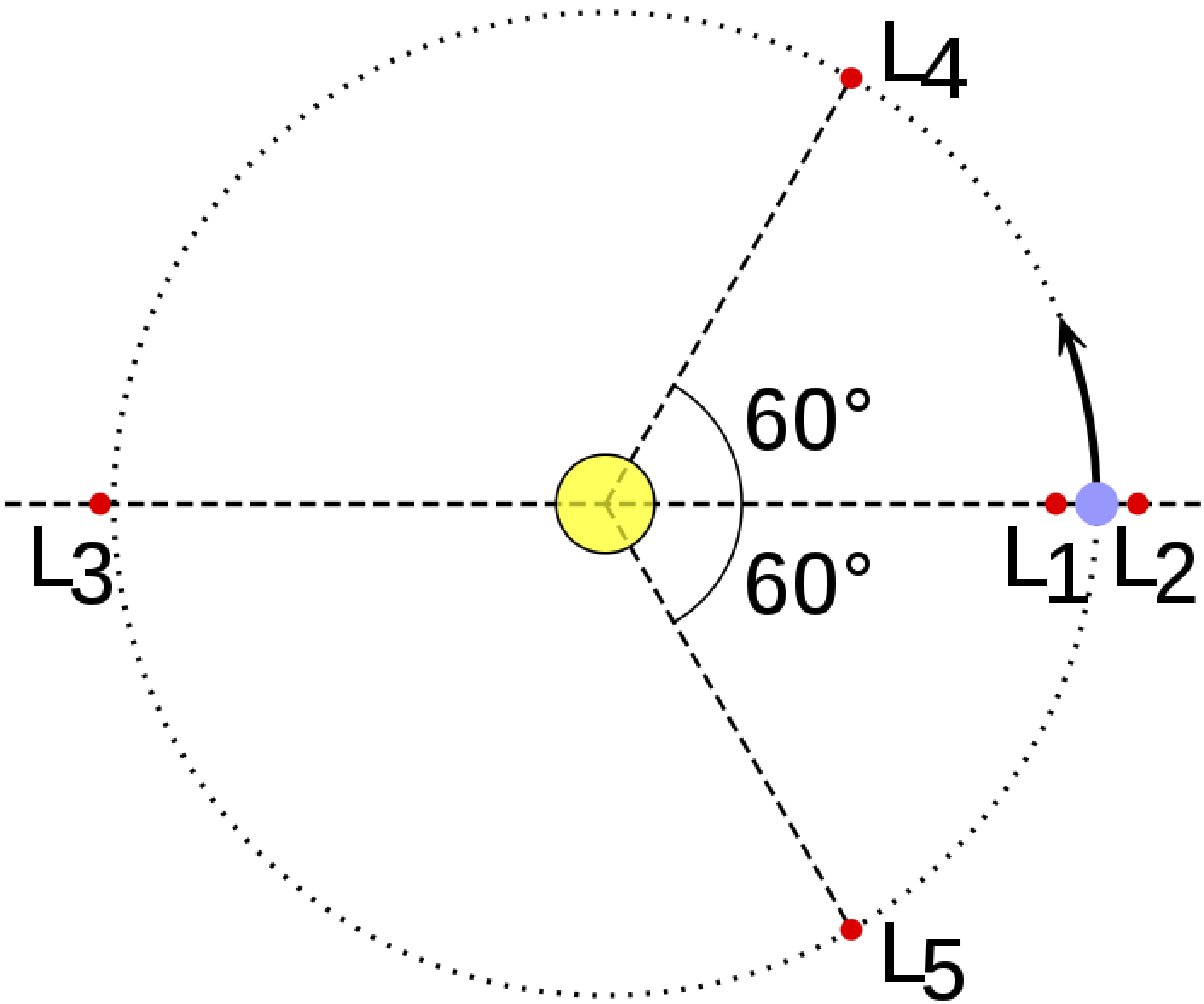


Left: A bottle of Comet Wine. From Patrick Moore's photograph collection. Right: "The Ghost of a Flea," painted by British artist William Blake in 1819-20. The Great Comet of 1811 is apparently represented in the starry background.

SPECIAL TOPIC: TROJAN ASTEROIDS

In any orbital configuration involving two, and only two, objects – for example, Earth and the sun – the orbital motion can be solved directly from Isaac Newton's Law of Universal Gravitation; the mathematical solution is complete and analytical. As soon as additional objects are added to the mix, however, things become much more complex, and as it turns out there is no analytical solution to a three-body, or any "n"-body, orbital configuration. Instead, the addition of the third object is usually treated as a "perturbation" to the original two-body solution, and the resulting orbital motion is solved – or, more accurately, approximated – numerically. In practice, the actual performance of these calculations can be tedious and laborious, although with the advent of modern computers over the past few decades this can be handled with relative ease.

Various explorations of the "three-body problem" have nevertheless been an area of study for mathematicians for quite some time. In the late 18th Century the Swiss mathematician Leonhard Euler determined that there are three configurations wherein the gravitational pulls involved are such that the three objects will maintain the same orientations with respect to each other, and in 1772 the French-Italian mathematician Joseph-Louis Lagrange found two additional such configurations. The five locations where a third object can exist in these configurations



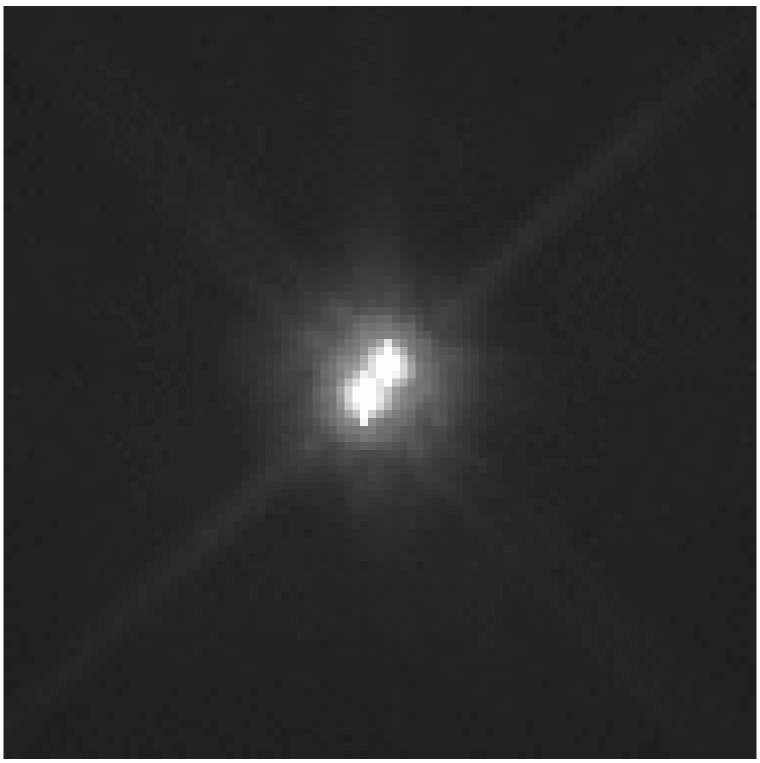
The various Lagrangian points within a generic three-body system. In the specific case of planets and Trojan asteroids, the sun is the yellow circle in the center and the planet – Jupiter, and/or another planet – is the smaller blue circle.

are now known as "Lagrangian points," and are numerically designated as L1 through L5.

The L1 through L3 points are on the same line as the line between the two primary objects. In the Earth-sun system, L1 is 1.6 million km directly sunward of Earth, L2 is the same distance in the opposite direction, i.e., beyond Earth, and L3 is just beyond Earth's orbit on the far side of the sun from Earth. L4 and L5, meanwhile, are in the same orbit but 60 degrees ahead of and behind the secondary object; in the Earth-sun system, L4 is in Earth's orbit but 60 degrees ahead of Earth, while L5 is 60 degrees behind Earth. L4 and L5, in particular, are gravitationally stable, and while L1 through L3 are not, spacecraft in halo orbits around these points can remain in a stable configuration.

Several spacecraft have indeed been positioned at some of the Lagrangian points in the Earth-sun system. The NASA/ESA SOlar and Heliospheric Observatory (SOHO) spacecraft, which has discovered numerous comets and which is discussed in several other "Ice and Stone 2020" presentations, is at L1, as is NOAA's Deep Space Climate ObserVatoRy (DSCOVR) mission, and as was the International Sun-Earth Explorer 3 (ISEE-3) spacecraft before it was sent to Comet 21P/Giacobini-Zinner (renamed as ICE) in the mid-1980s. Among other missions, ESA's Herschel Space Telescope and Gaia spacecraft are at L2, as was China's Chang'e 2 spacecraft before it was sent off to encounter the near-Earth asteroid (4179) Toutatis in 2012; the James Webb Space Telescope, now scheduled for launch in late 2021, will also be placed at L2.

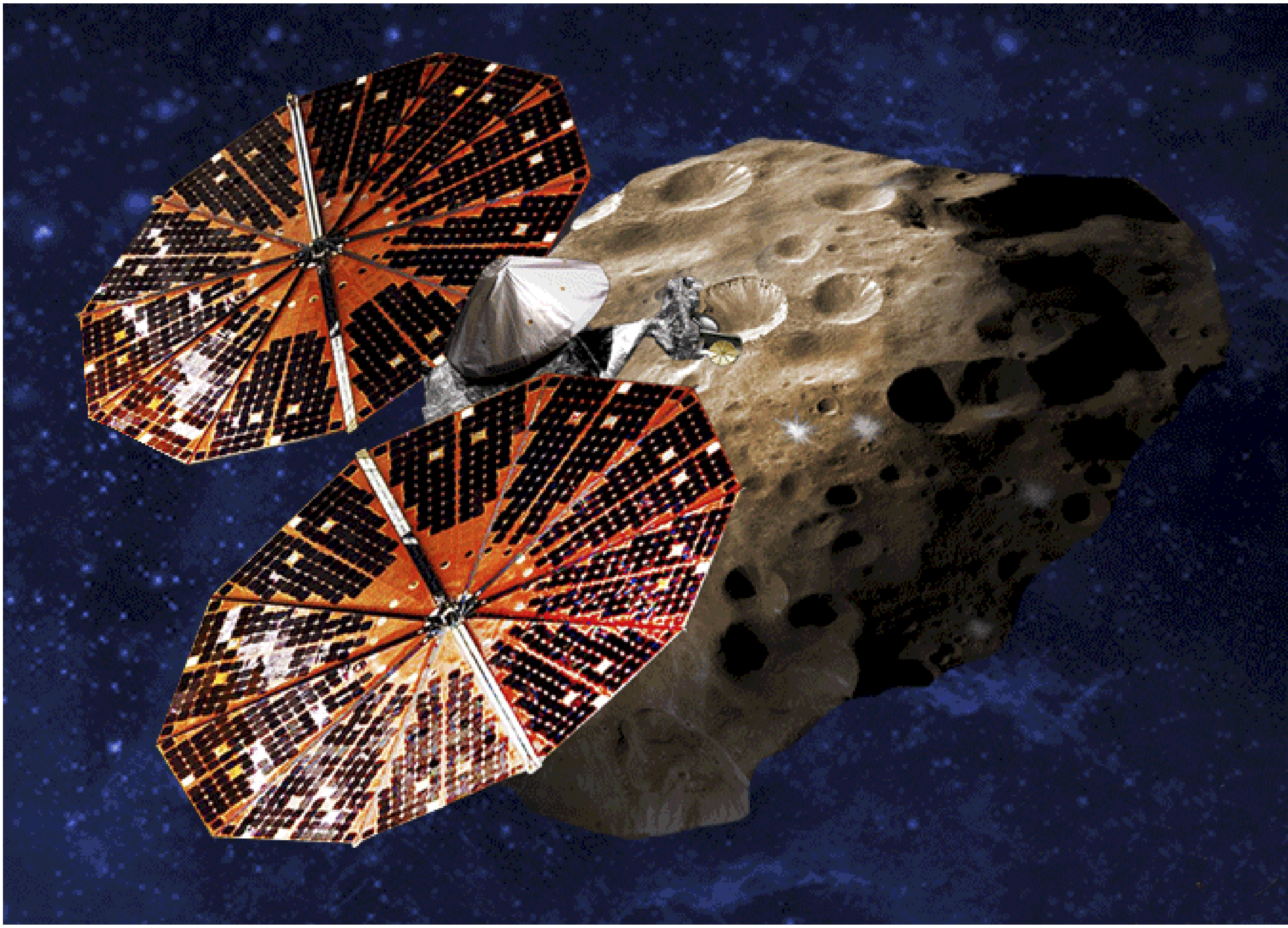
In the Earth-moon system, the Kordylewski dust clouds – discussed in a previous "Special Topics" presentation – are in and around the L4 and L5 points. The orbiting "space habitat" envisioned by the L5 Society – since merged into what is now the National Space Society – was, as the name implies, to be placed at the Earth-moon L5 point.



Hubble Space Telescope image of (617) Patroclus and its moon Menoetius taken February 13, 2018. Courtesy NASA/Southwest Research Institute.

Since the L4 and L5 points in planets' orbits are gravitationally stable, it would seem reasonable to think that natural objects, like asteroids, can exist in these locations. The American astronomer Edward Barnard, then based at Yerkes Observatory in Wisconsin, visually discovered the first-known such object near the Jupiter L5 point on the evening of September 12, 1904, which he at first mistakenly believed was Saturn's recently-discovered outer moon Phoebe but which he later concluded was a different object; by that time, however, it was hopelessly "lost." This object, which was later designated as 1904 RD, was finally found in late 1999 when Gareth Williams at the Minor Planet Center identified it (together with several other objects photographed on various occasions beginning in the mid-1970s) as being identical to the asteroid now known as (12126) 1999 RM11, which had been discovered in September of that year by the LINEAR program in New Mexico. Meanwhile, the German astronomer Max Wolf at Heidelberg Observatory discovered the first asteroid to be recognized as orbiting near a Jupiter-sun Lagrangian point when, on February 22, 1906, he found the asteroid now known as (588) Achilles orbiting near the L4 point. August Kopff, also at Heidelberg, discovered the asteroid now known as (617) Patroclus, orbiting near the Jupiter-sun L5 point, on October 17 of that same year, and then found (624) Hektor near the L4 point on February10 of the following year.

More and more such asteroids began to be discovered in subsequent years, and today over 7000 have been found, roughly 2/3 of these being in or around the L4 point. Current estimates are that there may be as many as several hundred thousand such objects down to a size of 1 km. Following the names given to the first-discovered representatives, these asteroids are collectively called "Trojan" asteroids and, per agreement within the astronomical community, they are given names of characters from the Trojan War as described in Homer's Iliad and by other classical Greek authors. The asteroids around L4 are given names of Greek characters from that mythical conflict and those



Artist's conception of NASA's Lucy mission (scheduled for launch in October 2021) during a flyby of a Jupiter Trojan asteroid. Courtesy NASA.

around L5 are given names of Trojan characters; since Patroclus and Hektor were named before this convention was established they are essentially "spies" within their "enemies'" camps.

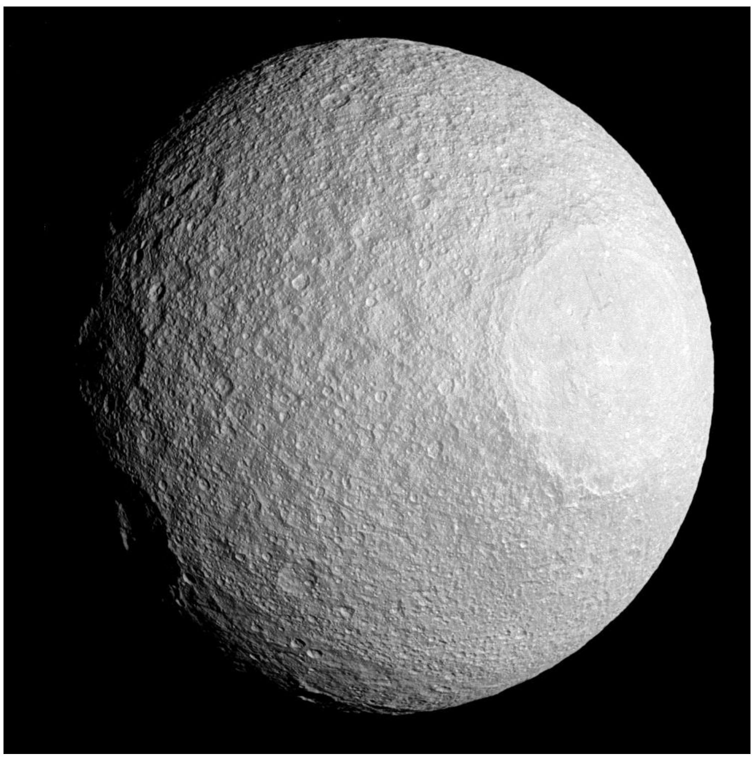
(624) Hektor is the largest of the Trojan asteroids, with an approximate diameter of 225 km. (588) Achilles, (911) Agamemnon, and (3451) Mentor are all next, with approximate diameters in the range of 130 to 140 km, with additional known Trojans gradually becoming smaller. A handful of Trojans are known to have moons, the first-discovered such object being a companion to (617) Patroclus discovered in September 2001 by a team led by William Merline utilizing the 8.1-meter Gemini North telescope at Mauna Kea in Hawaii. This companion, since named Menoetius, almost makes a "double asteroid" system with Patroclus itself, the two objects having approximate diameters of 120 km (Patroclus) and 110 km (Menoetius) and separated by 680 km. (624) Hektor also has a moon, a much smaller (12 km) object discovered in 2006 by a team led by Franck Marchis utilizing the 10-meter Keck II telescope in Hawaii and since named Skamandrios. A team led by Keith Noll utilizing the Hubble Space Telescope discovered a small moon – probably no more that about 1 km in diameter – accompanying (3548) Eurybates in September 2018, and after confirming this object a year later announced its discovery earlier this year.

In physical terms, most of the Trojan asteroids that have been examined appear to be quite dark, with some exhibiting a somewhat reddish coloration and/or features in their spectra that are suggestive of organic compounds. There is evidence that at least some of the Trojans may be inactive comet nuclei, in fact a detailed study of Patroclus and Menoetius in 2006 suggests that their average density is less than that of water. Other Trojans, for example Hektor, appear to have a significantly higher density than this, so, perhaps not too surprisingly, the bodies making up the population of Trojan asteroids appear to have come from a wide variety of original objects.

We should get a much closer look at some of the Trojan asteroids with NASA's Lucy mission, currently scheduled for launch in October 2021. As currently planned, Lucy will be visiting four Trojans around the L4 point – (3548) Eurybates (and its recently-discovered small moon), (15094) Polymele, (11351) Leucus, and (21900) Orus – between August 2027 and November 2028, then return to Earth for a gravity-assist flyby that will send it to the L5 point and an encounter with (617) Patroclus and its moon Menoetius in March 2033. Lucy is discussed in more detail in a previous "Special Topics" presentation.

Although the term "Trojan asteroid" has generally referred to objects orbiting the sun in or near Jupiter's L4 or L5 points, it is appropriate to ask whether or not other planets also have their own sets of Trojan asteroids in their respective L4 and L5 locations. And the answer is "yes;" as of now, four other planets are now known to have Trojan asteroids, all of these objects having been discovered within the past three decades.

The first-known Neptune Trojan was 2001 QR322, discovered on August 21, 2001, by a survey effort called the Deep Ecliptic Survey, led by Robert Millis, from Cerro Tololo Inter-American Observatory in Chile; it orbits near the Neptune L4 point. Since then almost thirty additional Neptune Trojans have been found, most of these being around L4; only a handful have been found around the L5 point, and one more, (316179) 2010 EN65, is centered around Neptune's L3 point but shifts back and forth between L4 and L5. The preponderance of objects near L4 is almost certainly due to an observational bias, since for the time being Neptune's L5 region is located against the star-rich Milky Way area in Sagittarius. Distance also plays a role; even though the largest-known Neptune Trojans are close to 200 km in diameter, these are still no brighter than 19th or 20th magnitude.



Cassini image of Saturn's large moon Tethys. The large crater on the right is Odysseus. Courtesy NASA.

With Neptune's proximity to the Kuiper Belt it is likely that many of the Neptune Trojans are captured objects from that population. It is also quite possible that the total number of Neptune Trojans is several times that of the Jupiter Trojans, it's just that the majority of these are too small, and thus too faint, to detect with most telescopes available nowadays.

Only a small handful of Neptune Trojans have been well enough observed to have permanent numbers assigned to them. By agreement amongst the international community of astronomers, Neptune Trojans will be assigned names of Amazon warriors, the all-female tribe who fought on the side of the Trojans during the Trojan War. As of right now, two of these objects have been so named: (385571) Otrera and (385695) Clete.

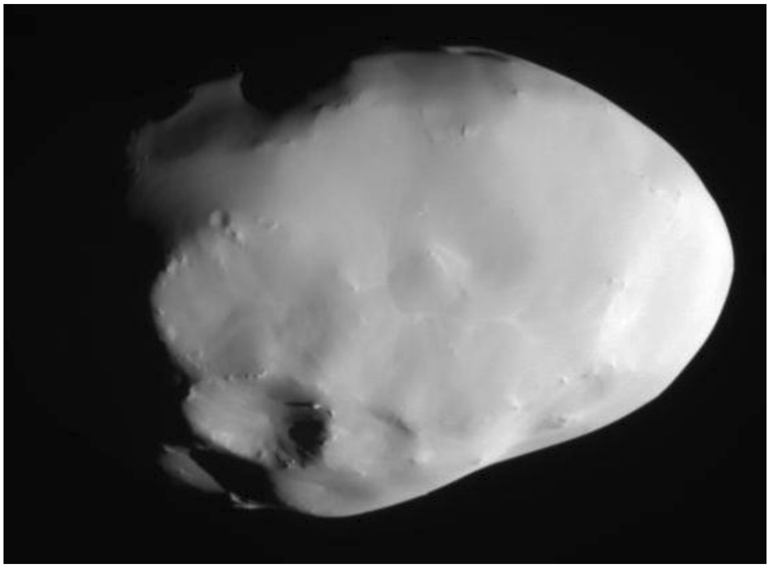
At this time only two Uranus Trojans have been discovered: 2011 QF99, discovered during the course of a survey program conducted with the Canada-France-Hawaii Telescope at Mauna Kea, and 2014 YX49, discovered by the Pan-STARRS survey; both are near the Uranus L4 point. Due to the proximity of both Neptune and Saturn and the resulting orbital resonance patterns, orbits near the Uranus L4 and L5 points are not stable over long periods of time, and thus both of these objects are only temporary Uranus Trojans. They and any other Uranus Trojans – past, present, and future – are likely Centaurs – discussed in a previous "Special Topics" presentation – that have been temporarily captured into that orbital configuration.

Saturn does not have any known Trojan asteroids although, curiously, two of its larger moons have "Trojan" moons at the L4 and L5 points of their respective orbits around Saturn. Tethys (diameter 1060 km) has Telesto (average diameter 25 km) at its L4 point and Calypso (average diameter 21 km) at L5, while Dione (diameter 1120 km) has Helene (average diameter 35 km) at its L4 point and the much smaller Polydeuces (average diameter 2.5 km) at L5.

The first planet other than Jupiter known to have a Trojan asteroid was Mars when, on June 20, 1990, David Levy and Henry Holt, who were conducting the photographic survey program on the 46-cm Palomar Schmidt telescope in the absence of Eugene and Carolyn Shoemaker – this program being discussed in a previous "Special Topics" presentation – discovered the asteroid now known as (5261) Eureka near Mars' L5 point. Since then a handful of additional objects have been discovered orbiting near Mars' L5 point, two of which have been confirmed as being Mars Trojans, and one additional Mars Trojan, (121514) 1999 UJ7, has been found near the Mars L4 point.

(5261) Eureka is a relatively small object, with an approximate average diameter of 1.3 km, and the other Mars Trojans are even smaller, being 1 km in size or smaller. Eureka also apparently has a moon, designated as S/2011 (5261) 1, that was announced in 2014 based upon photometric measurements, and appears to be no more than 500 meters across. There is speculation that the smaller objects near L5 – and presumably Eureka's moon as well – are fragments of Eureka that have been ejected over time due to its rapid rotation (its rotation period being 2.69 hours).

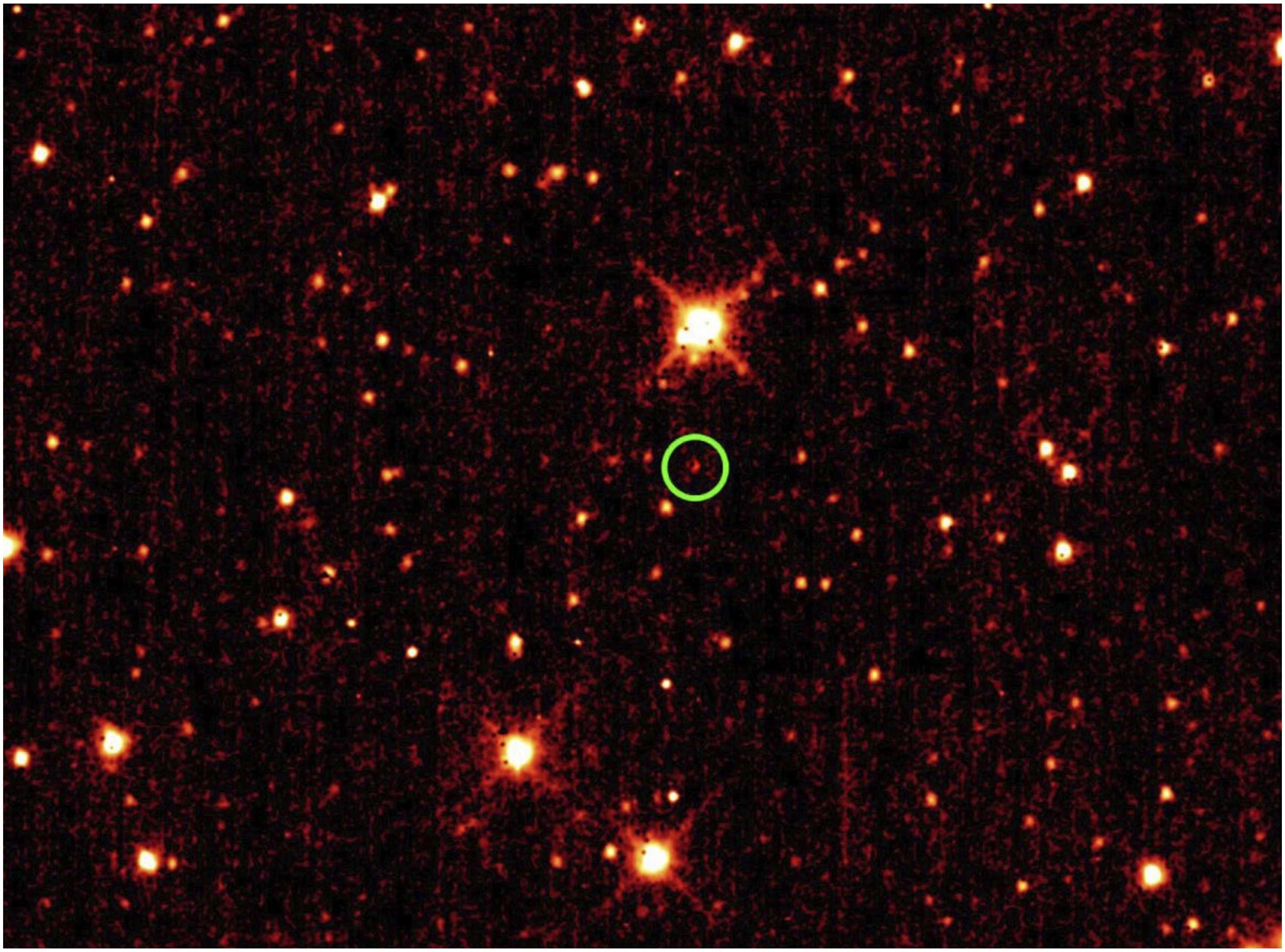
Following Eureka's discovery and its determination as being a Mars Trojan, David Levy attempted to start a new tradition wherein such objects would be named after expressions of joy – Eureka! ("I have found it!") supposedly having been uttered by the ancient Greek physicist Archimedes after he had just discovered what we now know as "Archimedes' principle" wherein a body placed in water displaces a volume of water equivalent to its own mass. At this time, however, only five confirmed (or candidate) Mars Trojans have received permanent numbers and Eureka is the only one of these that has thus far received a name.



Cassini images of the two "Trojan" moons of Saturn and its largest moon Tethys. Above: Telesto, at the Saturn-Tethys L4 point. Bottom: Calypso, at the Saturn-Tethys L5 point. All images courtesy NASA.

For obvious reasons there would be a lot of interest in possible Earth Trojans, but because such objects would generally be visible at relatively small elongations from the sun – and also would thus have non-trivial fractions of their surfaces in shadow due to the resulting phase angle – they would be difficult to detect. A few asteroids in close to Earth-resonant orbits have been detected over the past two to three decades, but the first-known – and thus far only known – Earth Trojan wasn't discovered until October 1, 2010, when NASA's Wide-field Infrared Survey Explorer (WISE) spacecraft detected 2010 TK7. This object, which is located near the Earth-sun L4 point, travels in a somewhat elliptical – eccentricity 0.19 – and inclined – inclination 21 degrees – orbit which can carry it as close as 0.13 AU from Earth at times and out close to the Earth-sun L3 point at other times. At the time of its discovery it was at the part of its trajectory that had carried it out to an elongation near 90 degrees, which contributed quite a bit towards making its discovery possible in the first place.

Because of the relative difficulty in observing it, there is not much information available about 2010 TK7's physical nature at this time. Its overall brightness, never brighter than about 20th or 21st magnitude, suggests that it is quite small, with the "best" estimates placing its diameter in the neighborhood of 300 meters. It is somewhat amenable to observation with large telescopes in the southern hemisphere right now, as its present elongation is close to 90 degrees and it should be brightest about a month from now as it approaches to 0.22 AU of Earth in early December (by which time a rapidly increasing phase angle will introduce a rather distinct fading). Perhaps, then, we'll know



One of the discovery images of the "Earth Trojan" asteroid 2010 TK7 (circled), taken by NASA's Wide-field Infrared Survey Explorer (WISE) spacecraft on October 1, 2010. Courtesy NASA/Jet Propulsion Laboratory/CalTech/UCLA.

more about this elusive object in Earth's vicinity within the not-too-distant future.

Any Trojan asteroids in Venus' or Mercury's orbits would be all but impossible to detect from Earth – unless, potentially, with space-based coronagraphs like those aboard the SOHO spacecraft, although no such objects have been detected. One object, 2013 ND15 – discovered by the Pan-STARRS survey in July 2013 but only observed for four weeks – is a potential temporary L4 Venus Trojan, although its orbital eccentricity of 0.61 carries it within Mercury's orbit and outside Earth's orbit. 2013 ND15 is a distinctly small object, no more than a few tens of meters in diameter, and since it experiences orbital resonances with Earth, Venus, and Mercury its present orbital configuration is not stable.

A 2011 study authored by Apostolos Christou in Northern Ireland and Paul Wiegert in Ontario identified several small main-belt asteroids as sharing the same orbits as the large asteroids (1) Ceres and (4) Vesta. Such orbits are unstable over long time-periods and thus any "Trojan" asteroids to these objects would only be temporary, although on the other hand there is a relatively large population of objects that could provide occupants for such orbits over long timescales. In any event, such analyses demonstrate that the solar system we see right now is a "snapshot" that only really applies to the here and now, and that things do change over the lifetime of the solar system.

SPECIAL ADDENDUM

In light of the ever-increasing number of discoveries of Jupiter Trojan asteroids, the IAU has recently decided that these objects with absolute magnitudes (i.e., apparent magnitudes if viewed from heliocentric and geocentric distances of 1.0 AU at a phase angle of 0 degrees) fainter than 12 can be named for Olympic athletes.

The aforementioned recently-discovered moon of (3548) Eurybates has just been named "Queta," after Norma Enriqueta Basilio Sotelo, who at the 1968 Olympic games in Mexico City became the first woman to light the Olympic flame.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