ICE & STONE 2020

WEEK 17: APRIL 19-25, 2020

Presented by The Earthrise Institute

#17

Authored by Alan Hale

THIS WEEK IN HISTORY

APRIL 20, 1910: Comet 1P/Halley passes through perihelion at a heliocentric distance of 0.587 AU. Halley's 1910 return, which is described in a previous "Special Topics" presentation, was quite favorable, with a close approach to Earth (0.15 AU) and the exhibiting of the longest cometary tail ever recorded.

APRIL 20, 2025: NASA's Lucy mission is scheduled to pass by the main belt asteroid (52246) Donaldjohanson. Lucy is discussed in a previous "Special Topics" presentation.

APRIL 21, 2024: Comet 12P/Pons-Brooks is predicted to pass through perihelion at a heliocentric distance of 0.781 AU. This comet, with a discussion of its viewing prospects for 2024, is a previous "Comet of the Week."

APRIL 22, 2020: The annual Lyrid meteor shower should be at its peak. Normally this shower is fairly weak, with a peak rate of not much more than 10 meteors per hour, but has been known to exhibit significantly stronger activity on occasion. The moon is at its "new" phase on April 23 this year and thus the viewing circumstances are very good.

COVER IMAGE CREDIT:

Front and back cover: This artist's conception shows how families of asteroids are created. Over the history of our solar system, catastrophic collisions between asteroids located in the belt between Mars and Jupiter have formed families of objects on similar orbits around the sun.

Data from NASA's NEOWISE project, based on observations made by the Wide-field Infrared Survey Explorer (WISE), have revealed the sizes and reflectivity of members of these asteroids families. The findings are helping scientists better understand how the families formed and evolved. NEOWISE is the asteroid-hunting portion of NASA's Wide-field Infrared Survey Explorer, or WISE, mission. Courtesy of NASA/JPL-Caltech.

19 20 21 22 APRIL 23 24 25

APRIL 23, 1066: Comet 1P/Halley passes 0.104 AU from Earth, one of the closest approaches it has made to our planet. Halley was exceptionally bright during its 1066 return, as is discussed in a previous "Special Topics" presentation; it is depicted on the Bayeux Tapestry that commemorates the Battle of Hastings, and in Native American petroglyphs at Chaco Canyon, New Mexico.

19 20 21 22 23 APRIL 24 25

APRIL 24, 1895: The centaur (2060) Chiron is recorded on a photograph taken from Harvard Observatory, the earliest image of any centaur. The image was identified by Harvard astronomers William Liller and Lola Chaisson after Chiron's discovery in 1977. Chiron and other centaurs are discussed in a previous "Special Topics" presentation.

APRIL 24, 1932: Karl Reinmuth at Heidelberg Observatory in Germany discovers the near-Earth asteroid now known as (1862) Apollo. This was the first-known member of the "Apollo-type" asteroids, those with a perihelion distance within Earth's orbit. After 1932, Apollo itself was lost until its recovery in 1973. The Apollo-type asteroids and other near-Earth asteroids are discussed in a previous "Special Topics" presentation.

APRIL 24, 1985: Carolyn and Eugene Shoemaker discover the main-belt asteroid now known as (4151) Alanhale from Palomar Observatory in California. I am using this asteroid as an illustrative example of how asteroids are designated and named in this week's "Special Topics" presentation. Alanhale will be at opposition this coming August, when it should be around 17th magnitude.

19 20 21 22 23 24 APRIL 25

APRIL 25, 1983: The InfraRed Astronomical Satellite (IRAS) spacecraft discovers a "fast-moving object" which is later found to be a comet and which is also independently discovered by amateur astronomers Genichi Araki and George Alcock. Comet IRAS-Araki-Alcock passed just 0.031 AU from Earth the following month, the closest confirmed cometary approach to Earth in the 20th Century. It is a future "Comet of the Week."

APRIL 25, 1990: Astronauts aboard the Space Shuttle Discovery deploy the Hubble Space Telescope. Hubble has revolutionized almost every field of astronomy since then, and along the way has taken numerous images of asteroids and comets, some of which are featured in various "Ice and Stone 2020" presentations.

***THERE ARE NO ENTRIES FOR APRIL 19.**

COMET OF THE WEEK: AREND-ROLAND 1956H

Perihelion: 1957 April 8.03, q = 0.316 AU

Comet Arend-Roland and its "anti-tail." Wide-field view, taken April 26, 1957, by Eugenio Mendoza and Marlyn Krebs from McDonald Observatory in Texas.

There weren't any bright comets that appeared the year I was born, 1958, but two bright comets appeared the previous year. These two objects were the brightest comets to become easily visible from the northern hemisphere since the return of Comet 1P/Halley in 1910.

The first of the two comets was discovered by Sylvain Arend and Georges Roland on routine asteroid patrol photographs taken at Uccle Observatory in Belgium on November 8, 1956, although the comet's images weren't noticed until a week and a half later. Being around 11th magnitude at the time and close to opposition, it was found to be five months away from perihelion passage, and it brightened steadily over the coming months as it approached the inner solar system. During January 1957 it was between 9th and 10th magnitude, and it brightened further to about 7th magnitude by the time it disappeared into evening twilight around the end of February.

After being hidden in sunlight for about a month, Comet Arend-Roland became briefly visible from the southern hemisphere around the beginning of April. The comet's elongation remained small – never exceeding 18 degrees – but according to reports, including those made by scientists in Antarctica for the International Geophysical Year (which officially began on July 1), it was as bright as 2nd magnitude with a tail up to 5 degrees long. Before long it disappeared back into sunlight en route to a second conjunction with the sun.

Around April 20 Comet Arend-Roland emerged back into the northern hemisphere's evening sky, rapidly traveling northward; closest approach to Earth (0.57 AU) was in fact on the 20th. Initially it was as bright as magnitude 1 or 0, with a bright dust tail – likely enhanced due to forward scattering of sunlight – 25 to 30 degrees long. It faded fairly rapidly, being close to 3rd magnitude, although still with a 15-degree-long tail, by the end of April.

A particularly striking feature of Comet Arend-Roland during the latter days of April was the presence of a prominent sunward-pointing tail, or "anti-tail." Initially this appeared as a somewhat broad fan, which became narrower each day until April 25 when it

Above: Close-up view, taken April 25, 1957 by Eric Lindsay from Armagh Observatory in Northern Ireland. Photo provided courtesy John McConnell. Right: Comet Arend-Roland on May 2, 1957, as photographed by Reginald Waterfield in England.

appeared as a very narrow "spike" extending up to 15 degrees from the coma. During subsequent days this expanded into a fan shape again, although on the opposite side of the coma from where it had been previously, and it also faded dramatically, disappearing by the first few days of May.

This "anti-tail" was due to dust grains that had been ejected from the comet before perihelion, which in turn lagged behind the comet as it made its passage through perihelion and began its trek away from the sun. This material remained in the plane of the comet's orbit, which Earth crossed on April 25; on that day, we were seeing this material exactly edge-on, and slightly askew on the days immediately before and after. The "anti-tail," then, was merely a projection effect, caused by sunlight being scattered off these dust grains in the comet's orbit. Various other comets have also exhibited "anti-tails," although that of Arend-Roland probably remains the most dramatic example.

By May the comet was entering northern circumpolar skies, and it faded below naked-eye visibility around the middle of that month. Visual observations continued until the latter part of June, and photographically it was followed until April 1958, by which time it had become very faint; two months earlier it had passed within a few arcminutes of the North Celestial Pole.

With the five months of lead time before perihelion passage Comet Arend-Roland was a well-studied comet from a scientific perspective including, as previously mentioned, by scientists involved with the International Geophysical Year. It was the first comet to be detected with radio telescopes, but such was the state of the technology at the time that little useful science could be obtained from these observations, other than rough examinations of the evolution of large-scale phenomena in the comet's coma and tail.

Comet Arend-Roland turned out to be a first-time visitor from the Oort Cloud, and the gravitational perturbations it encountered during its passage through the inner solar system were enough to place it into a slightly hyperbolic orbit and thus eject it from the solar system altogether. It will thus never be seen again . . . However, just a few months later another bright comet, Comet Mrkos 1957d, graced the nighttime skies of Earth, and this object will be a future "Comet of the Week."

SPECIAL TOPIC:
DESIGNATIONS AND NAMES OF “SMALL BODIES:

Throughout “Ice and Stone 2020” I refer to numerous specific objects, including in all of my “Comet of the Week” presentations as well as in several of my “Special Topics” presentations and in the lists of weekly historical events. It is appropriate, then, to discuss how these various objects are designated and named.

The conventions used for designating asteroids have changed somewhat over the decades, but, in general, most newly-discovered asteroids are assigned designations of the form:

<year>space<upper case letter><upper case letter><numerical subscript>

Examples would be 2020 AB and 2020 DC5.

In this scheme, the year refers to the year of discovery. The first letter corresponds to the half-month that the discovery took place: “A” is the first half of January, “B” is the second half of January, “C” is the first half of February, and so on. For traditional reasons, the letter “I” is skipped; thus, “H” refers to the second half of April, “J” refers to the first half of May, “K” refers to the second half of May, and so on, up through “Y,” which represents the second half of December.

The second letter of this designation scheme refers to the order of discovery within the half-month in question: “A” is the first asteroid discovered within that half-month, “B” the second asteroid discovered, and so on. Once again, the letter “I” is skipped; thus, the eighth asteroid discovered within a half-month would be “H,” the ninth would be “J,” the tenth would be “K,” and so on, up through “Z,” which would be the 25th. At this point, the letters rewind with a numerical subscript: the 26th asteroid discovered within a half-month would be “A1,” the 27th would be “B1,” the 50th would be “Z1,” the 51st would be “A2,” the 75th would be “Z2,” the 76th would be “A3,” and so on, for as far as necessary. With the advent of the comprehensive survey programs that became operational during the last couple of years of the 20th Century there have been some half-months that have needed three-digit numerical subscripts.

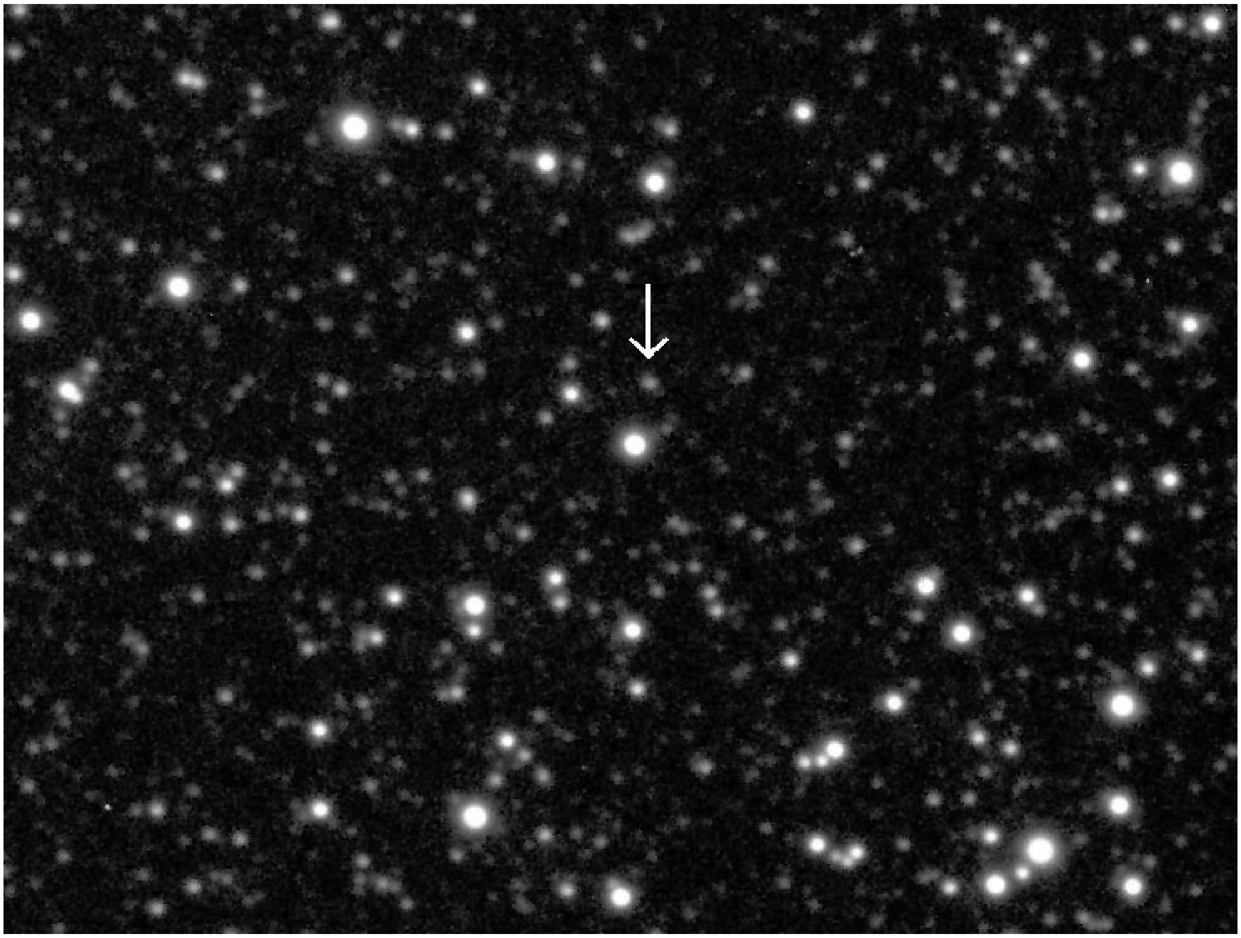
In the above examples, 2020 AB would be the second asteroid discovered during the first half of January 2020, and 2020 DC5 would be the 132nd asteroid discovered during the second half of February 2020.

One significant departure from this scheme involves a series of collaborative programs between Palomar Observatory in California and Leiden Observatory in The Netherlands. In these programs series of photographs taken by Tom Gehrels with the 1.2-m Schmidt telescope at Palomar were carefully scrutinized by the husband-and-wife team of Cornelius and Ingrid van Houten at Leiden in searches for asteroids. The initial “Palomar-Leiden survey” was conducted in 1960, and any asteroids discovered via this survey received designations of the form <four digit number>space”P-L.” This survey was subsequently followed by three additional surveys in 1971, 1973, and 1977 that were designed to search specifically for Jupiter Trojan asteroids (which are discussed in a future “Special Topics” presentation). The asteroids discovered in these surveys were assigned designations in the form of <four digit number>space“T-” <survey> with <survey> being “1,” “2,” or “3” for the 1971, 1973, and 1977 surveys, respectively.

Examples of asteroids discovered during the course of these programs are 3540 P-L, 1180 T-1, 2255 T-2, and 3105 T-3.

Not every asteroid that is discovered and designated is a separate object from all others. Especially with main-belt asteroids, an object may be "discovered" and assigned new designations at various different oppositions. The IAU's Minor Planet Center is generally tasked, among other things, with finding various linkages between different designations and determining when they might refer to the same asteroid at different oppositions (or sometimes even the same opposition, but found by different surveys). Once such a link is established, an asteroid may then be recovered at future oppositions, and/or found in images taken at previous oppositions.

For example, several years ago the Minor Planet Center found that the asteroids that had been designated 1968 HD, 1976 SO1, 1979 FX1, 1982 SZ4, 1985 HV1, and 1985 JX were in fact all the same object, orbiting in the main asteroid belt with an orbital period of 5.6 years and an eccentricity of 0.14.



CCD image of a main-belt asteroid taken with the Las Cumbres Observatory network. (4151) Alanhale (marked) on June 6, 2019 – around the time of its previous opposition – from Cerro Tololo Inter-American observatory in Chile.

These designations are generally considered as temporary. During the first several decades that asteroids were being discovered they were assigned permanent numbers, usually written in parentheses, in the order of discovery. For example, the first asteroid discovered, Ceres, is (1), Pallas, the second asteroid to be discovered, is (2), Eros, the first known near-Earth asteroid, is (433), and so on. Some of these early-numbered asteroids were "lost" after discovery, although all of these have since recovered. (The longest period of being "lost" was for the near-Earth asteroid (719) Albert, which was discovered in 1911 and subsequently "lost" until it was accidentally re-discovered in 2000.)

Today, these permanent numbers are not assigned until an asteroid has been observed at several oppositions and its orbit is well-enough known such that there is no significant possibility that it might become "lost" within the foreseeable future. The multiple-designated asteroid in the above example has now been assigned the permanent number (4151). With the advent of the comprehensive survey programs during the past two decades the number of asteroids with well-determined orbits, and thus with permanent numbers, has skyrocketed; the highest assigned number at this writing is (545135). The vast majority of the higher-numbered asteroids are tiny and dim objects.

Once an asteroid has been numbered, it can be assigned a name. Per tradition, the person or entity that discovers an asteroid has the privilege of proposing a name, which must be approved by a special committee set up by the IAU for this purpose. According to current guidelines, this privilege remains for ten years once an asteroid has been assigned a number; after this time, anyone can propose a name.

Especially with all the surveys going on nowadays, the "discoverer" of an asteroid is not especially clear-cut, and the large majority of discoveries are made by survey programs – many of which operate at least semi-autonomously – and not by individual people. The exact definition of "discoverer" has changed a bit over the years, but today the operational definition is the entity that makes the "earliest-reported observations at the opposition with the earliest-reported second-night observation."

In continuing with the tradition of the names given to planets, the first asteroids were given names of gods or other entities from Greek or Roman mythology. However, after a while it became apparent that there are far more asteroids than there are gods, and astronomers accordingly began naming asteroids after family members, colleagues, benefactors, observatories, hometowns, and so on.

While most proposed names are acceptable, and are published within the Minor Planet Center's Minor Planet Circulars on a regular basis, there are some guidelines:

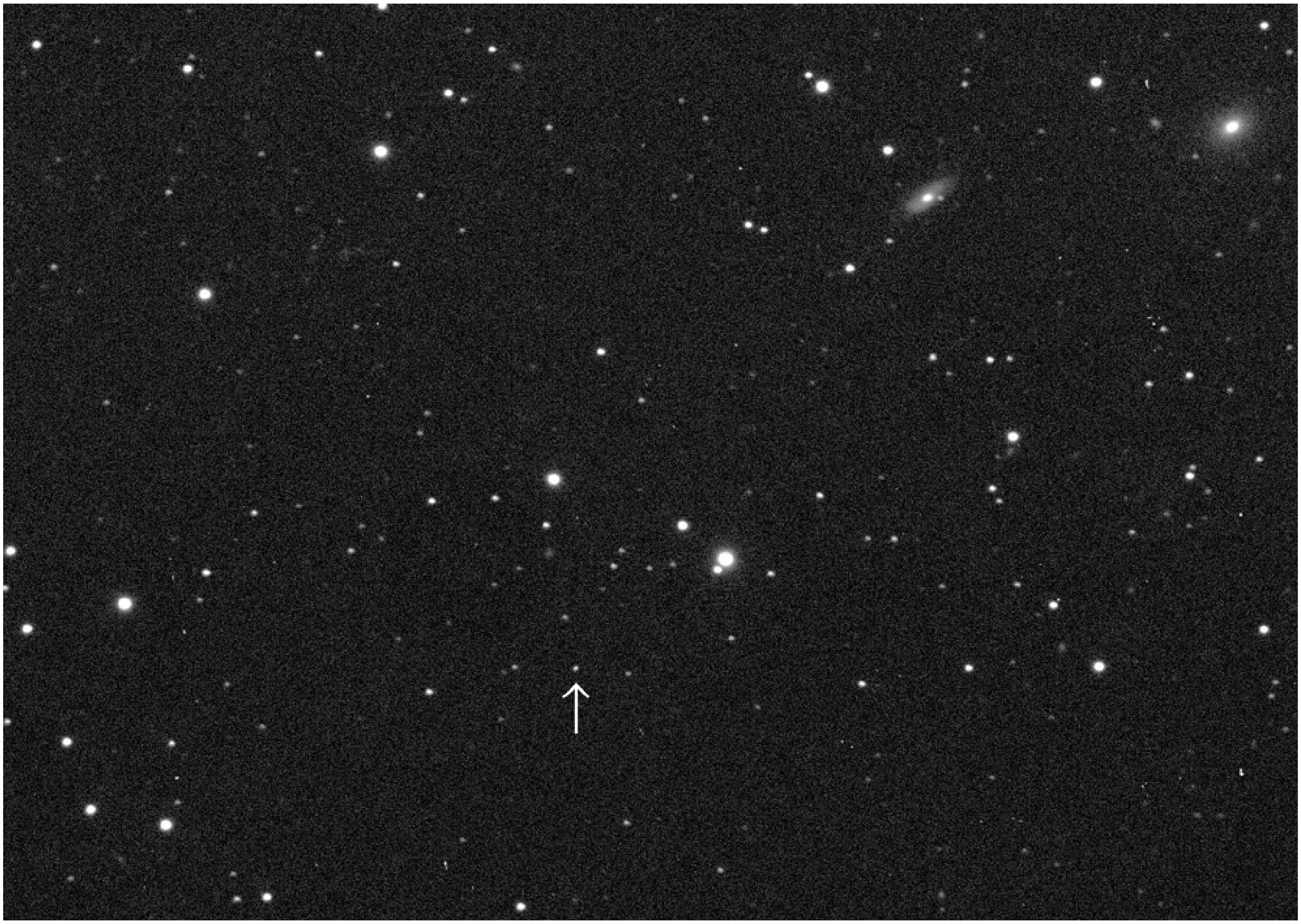
A name must be 16 characters or fewer in length;
Pronounceable (in some language);
Non-offensive.

Names or a purely or primarily commercial nature are not accepted, and names of persons or events known primarily for military or political activities are acceptable only after 100 years or more have elapsed since the person died and/or the event occurred.

Notwithstanding the general acceptance of names, there are certain types of asteroids where certain naming conventions hold. Apollo-type asteroids (i.e., those with perihelion distances within Earth's orbit) are still generally assigned names out of Greek or Roman mythology, and Aten-type asteroids (i.e., those with orbital periods of less than one year) are generally assigned names out of Egyptian mythology. Jupiter Trojans are assigned names of characters from the Trojan War, with asteroids in the leading group of Trojans (at the Jupiter-Sun L4 point) being named for Greek characters, and asteroids in the following group (at the Jupiter-Sun L5 point) being named for Trojan characters. (Two of the earliest-known Trojans, (617) Patroclus and (624) Hektor, were named before this convention was established, and are thus in the opposite "camps;" they perhaps can be considered as "spies.") Objects in the Kuiper Belt generally receive the names of creation deities.

Some of the many asteroid names can be considered humorous or otherwise "interesting." For example, there is (2309) Mr. Spock, named by the discoverer for his cat and not the Star Trek character. (The usage of pets' names for asteroids is now discouraged). There are also (3142) Kilopi and (11111) Repunit; the rationale for these names is left as an exercise for the reader.

Asteroid (4151), described above, was discovered by the husband-and-wife team of Eugene and Carolyn Shoemaker at Palomar on April 24, 1985, with the primary discovery designation being 1985 HV1. In April 1991 it was given the name Alanhale, the first celestial object, of two, that has my name on it. The second one, which came along four years later, is much better known.



CCD image of a main-belt asteroid taken with the Las Cumbres Observatory network. (23238) Ocasio-Cortez, taken from McDonald Observatory in Texas on November 4, 2019. This asteroid is one of numerous discoveries by the LINEAR survey in New Mexico that have been named for high school students who have won awards in the International Science and Engineering Fair; the future Representative in the U.S. Congress won such an award in 2007 a few months before this asteroid was named in her honor.

For what it's worth, (4151) Alanhale will be at opposition this coming August, when it should be around 17th magnitude. It should be a little over a magnitude brighter at the opposition at the beginning of 2023, when it will be close to perihelion.

The designation scheme for comets underwent some significant changes a quarter-century ago. Since several of the comets that I discuss in "Ice and Stone 2020," including several of those that are featured as "Comet of the Week," appeared before then, it is appropriate to examine the older scheme (usually referred to as "old style") before discussing the scheme currently in place ("new style").

The "old style" actually featured two sets of designations, one being referenced to a comet's discovery – this one usually considered to be "temporary" – and the other one being referenced to its perihelion passage, usually considered as being its "permanent" designation. The discovery scheme followed the format:

<year><lower case letter>

In this scheme the "year" would be the year of its discovery, and the lower case letter would indicate the order of discovery that year. (In this scheme, recoveries of expected returns of periodic comets were treated as "discoveries.") The first comet I ever observed, Comet Tago-Sato-Kosaka, had the designation 1969g, indicating that it was the seventh comet to be discovered or recovered in 1969.

This scheme has an obvious limitation in that it can only accommodate 26 discoveries. Up until the latter decades of the 20th Century this wasn't an issue, for there weren't that many comets being discovered. However, as observing techniques and instrumentation improved, and more and more comets began being discovered, it eventually became necessary to expand this scheme, into the following format:

<year><lower case letter><numerical subscript>

In 1987, the first year that this scheme became necessary, the 26th comet was 1987z, the 27th was 1987a1, the 28th was 1987b1, and so on. Although this never became necessary, if there had been a 52nd comet, that would have been 1987z1, the 53rd would have been 1987a2, the 54th would have been 1987b2, and so on.

Image of an "A/" object, discovered by the Pan-STARRS survey, taken with the Las Cumbres Observatory network. The object originally designated A/2017 U7, taken on August 21, 2019, from Cerro Tololo Inter-American Observatory in Chile. It clearly shows cometary activity, and has since been re-designated as C/2017 U7.

A couple of years after a particular given year, comets would be assigned "permanent" designations of the form:

<year>space<Roman numeral>

Here, the "year" is the year of perihelion passage, and the Roman numeral indicates the order of perihelion passage during that year. (The one- to two-year delay was meant to allow for any late discoveries that might take place.) Comet Tago-Sato-Kosaka's permanent designation is 1969 IX, indicating that it was the ninth comet to pass through perihelion in 1969.

As time went by, this dual-designation system became more and more cumbersome, plus there were occasions when very belated discoveries on old photographs required the assignment of permanent designations that were out of order when it came to the sequence of perihelion passages. At the beginning of 1995 the IAU implemented a new scheme, which did away with the perihelion-based designations altogether and instead utilized discovery designations of the form:

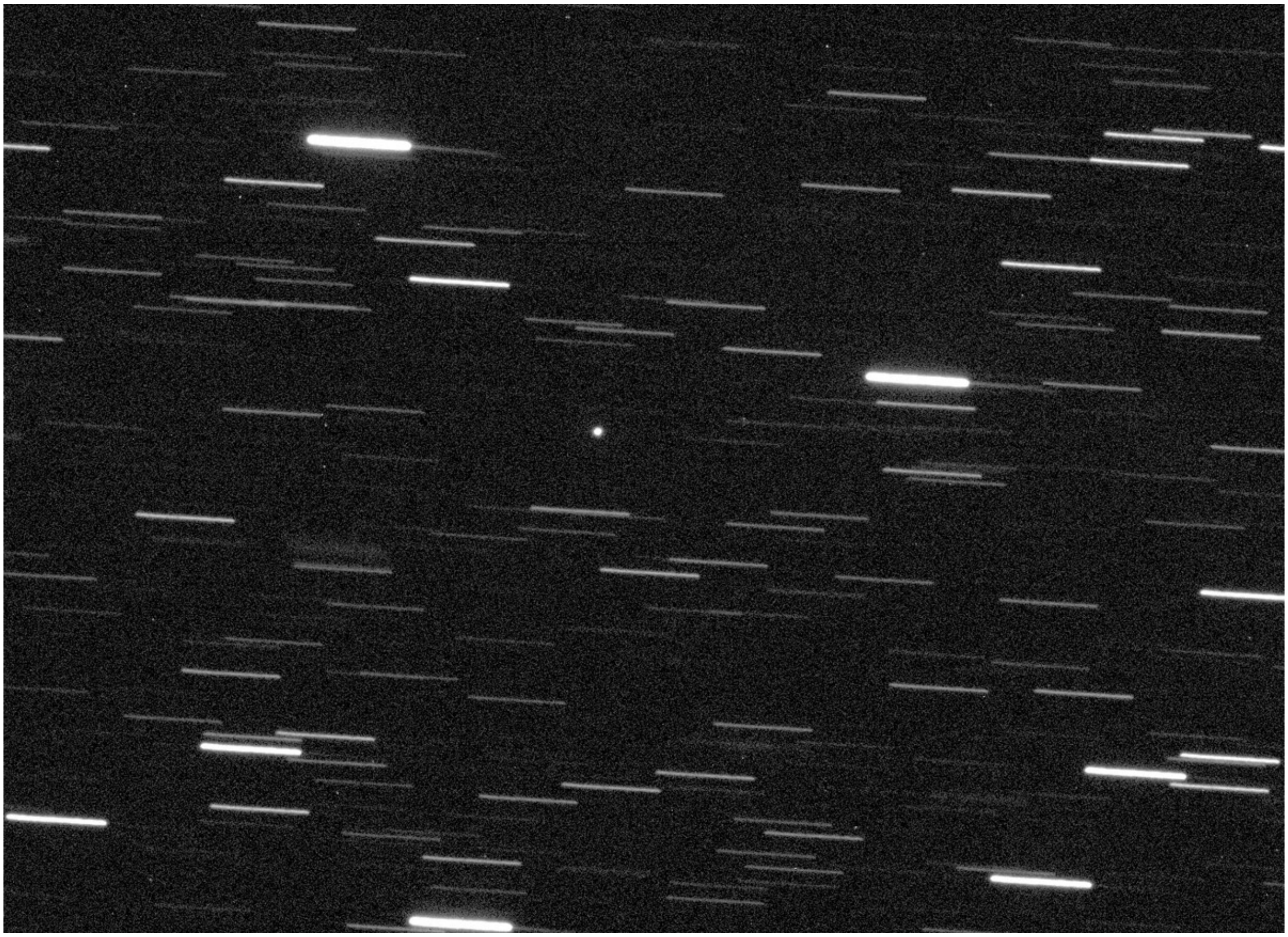


Image of an "A/" object, discovered by the Pan-STARRS survey, taken with the Las Cumbres Observatory network. The object A/2018 V3, taken August 20, 2019, from the South African Astronomical Observatory. Despite a perihelion distance of only 1.3 AU and a passage by Earth of 0.37 AU it remained completely asteroidal.

<prefix>/<year>space<upper case letter><number>

Here, "year" is the year of a comet's discovery, the upper case letter refers to the half-month of discovery in the same manner as in the discovery designations of asteroids, and the number is the numerical order of discovery within that half-month.

The prefix refers to the orbital and/or physical status of the comet. The two most commonly-utilized prefixes are "C," denoting long-period comets, and "P," denoting short-period comets. (Additional prefixes are discussed below.) The dividing line between "C" and "P" is somewhat arbitrary and has changed a bit over the usage of this scheme, but in general the current dividing line is an orbital period of 30 years.

The formal designation of the comet that bears my name is C/1995 O1, indicating that it was the first comet discovered during the second half of July 1995, and that it is a long-period comet.

It sometimes happens that an object will appear asteroidal at the time of its discovery and will accordingly be assigned an asteroidal discovery designation, however later observations may show that it is in fact a comet. In such cases, the asteroidal designation is maintained, but the appropriate “C” or “P” prefix will be placed in front of it to indicate that it is a comet. Examples are C/1997 BA6 and P/2001 MD7.

Since there is always a bit of uncertainty when it comes to the first expected return of a newly-discovered periodic comet, the first expected recovery will usually be assigned a designation in this scheme. Once that happens, the comet’s orbit can usually be considered as being well-known, and future “routine” recoveries do not receive a designation.

Once a periodic comet is considered “safe” and future recoveries can be considered “routine,” it will be assigned a sequential periodic comet designation of the form:

<number>”P/”<name>

When this scheme was implemented at the beginning of 1995 the “routine” periodic comets already known at that time were assigned the sequential numbers in the order they would have been assigned if the scheme had been in place at the time of their respective discoveries. Comet Halley, for example, is 1P/Halley (which can be shortened to 1P), Comet Encke is 2P/Encke (and shortened to 2P), and so on. At the time of the scheme’s implementation there were 115 numbered periodic comets, but due to the rapid increase of comet discoveries since then, the highest-numbered comet at this writing is 393P.

Other prefixes can be assigned in the discovery designations, as necessary and appropriate:

D: This means that the comet has disappeared. It is usually used when a periodic comet has been missed at several returns, and thus may well have disintegrated, and at the very least is “lost.” It can also mean that a comet has been destroyed, for example, Comet Shoemaker-Levy 9, which impacted Jupiter in 1994, is D/1993 F2. The “D” designation can also be utilized in place of “P” in the list of numbered short-period comets; one of the previous “Comet of the Week” comets is 3D/Biela, which was observed during six returns in the late 18th and early 19th Centuries but which has not been seen since 1852, and which has apparently completely disintegrated.

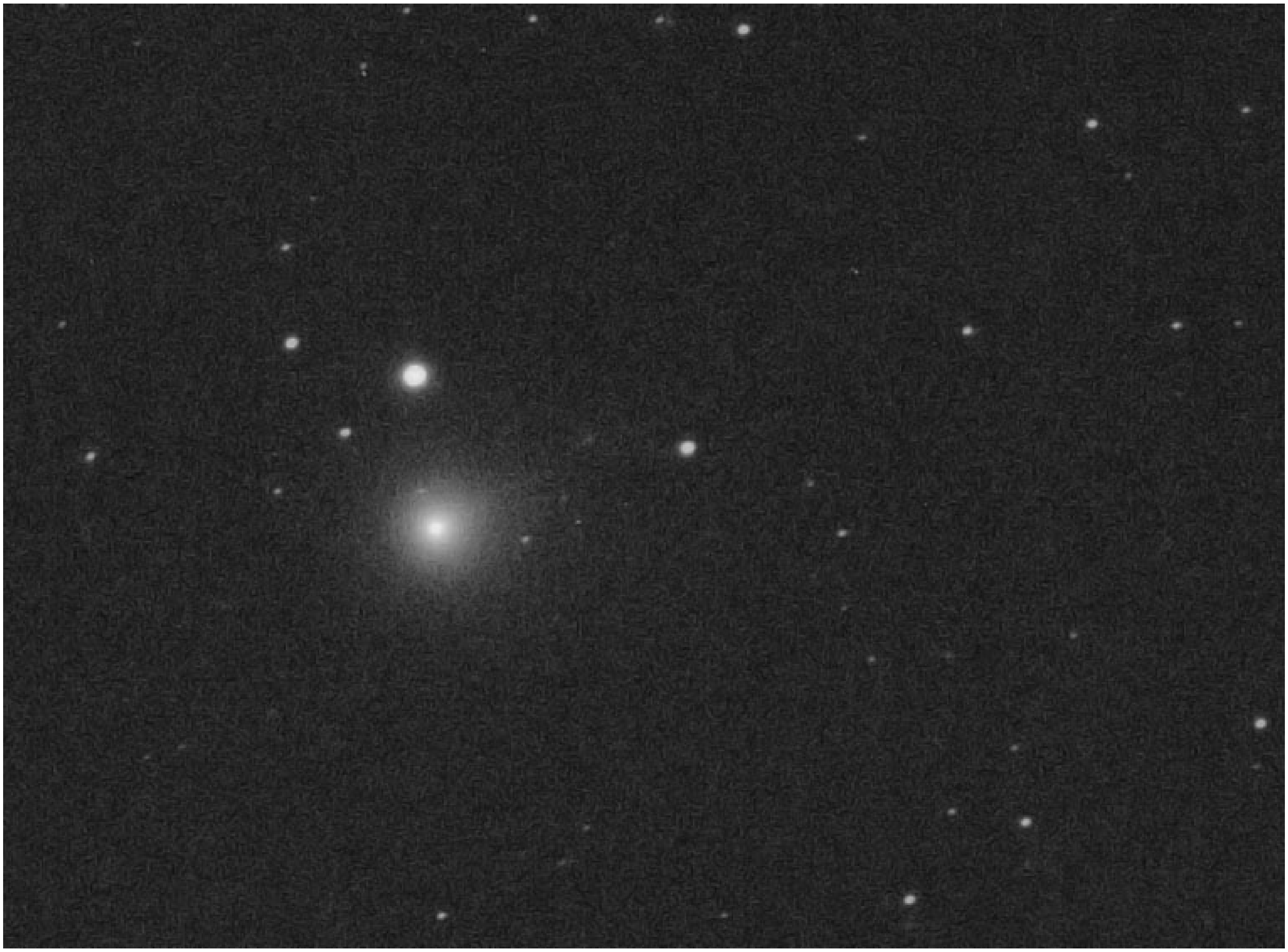
X: This means that the comet was so poorly observed that no reliable orbit can be calculated. For historical comets this designation is applied to comets that may well have been very bright but there simply isn’t enough accurate positional information that will allow the calculation of a valid orbit, whereas for more recent comets this may be applied to comets that appear on one or two old photographs or images, which is not enough information to allow for the determination of a valid orbit. One future “Comet of the Week” is an “X/”comet.

A: Originally this was meant to be assigned to objects that might have (mistakenly) been described as comets at the time of their discovery and assigned a cometary discovery designation, but later observations show are in fact asteroids. This prefix was never utilized in that sense, but more recently it has been applied to objects that are traveling in definite long-period cometary orbits but that have not exhibited cometary activity. If such an object later does show cometary activity, the prefix can be changed to “C.”

I: This prefix has just recently been added to the designation scheme, and applies to objects – cometary or otherwise – that are interstellar, i.e., they have arrived from outside the solar system on a hyperbolic orbit and will likewise leave the solar system. At this time, two such objects have been found, both of which will be individually discussed in future “Ice and Stone 2020” presentations.

S: This prefixed is utilized to designate newly-discovered moons around planets and asteroids, and is described below.

When the new designation scheme was implemented at the beginning of 1995, all the comets that had appeared prior to that time were retroactively assigned the appropriate "new style" designations. Since the literature references at the time of their respective appearances utilized "old style" designations, and since many of my earlier-observed comets did so as well, for my purposes here in "Ice and Stone 2020" I am using "old style" discovery designations for the pre-1995 comets.

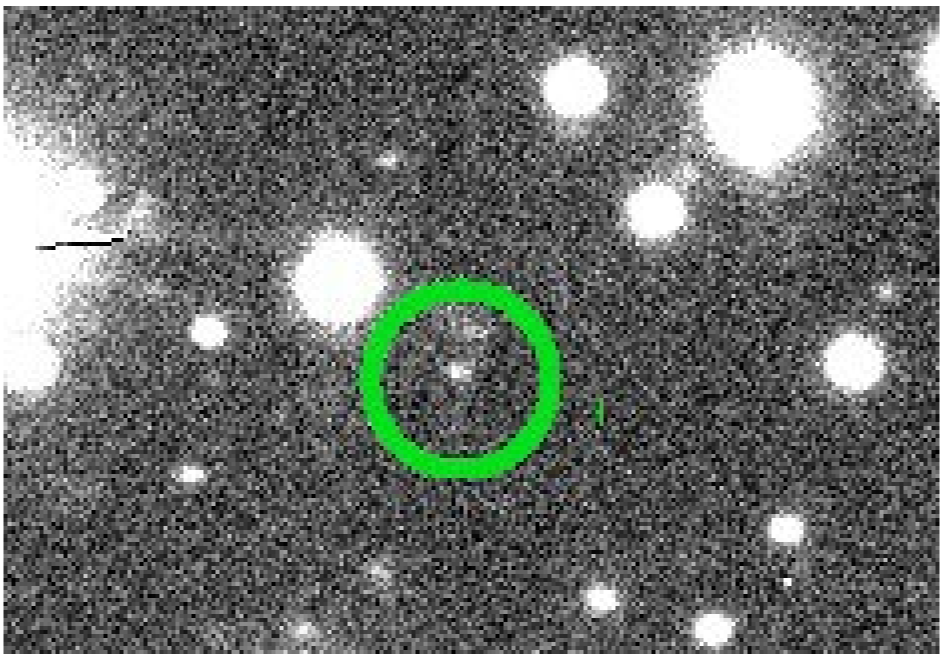


CCD image I took of Comet Machholz-Fujikawa-Iwamoto C/2018 V1 on November 15, 2018, with the Las Cumbres Observatory facility at Teide Observatory in the Canary Islands.

Since about the mid-18th Century comets have traditionally been named for their respective discoverers; this is a tradition from which I have benefited. There have been many occasions when a comet has been discovered almost simultaneously by more than one person, and accordingly has received both names; since Thomas Bopp in Arizona discovered the same comet I did at right about the same time, it accordingly received both our names. Sometimes there are three independent discoverers, and a comet accordingly has received all three names, but for obvious reasons the number of different names given to a comet has been limited to three. Since there have been occasions when a bright comet has suddenly appeared seemingly from out of nowhere and there are many independent discoveries of it, these comets have not necessarily received names but are simply known as the "Great Comet of" whatever year they appeared.

There have also been comets that have been jointly discovered by a team of two or more people. For quite some time the practice has been to give the comet the names of the different people involved in the discovery (again, up to three names), but with the advent of the comprehensive survey programs at the end of the 20th Century it has become the practice to name the comet after the program itself, for example, LINEAR, PANSTARRS, etc. (The various survey programs are discussed in a future "Special Topics" presentation.) Likewise, if a comet is discovered in images taken by a spacecraft, the comet will receive the name of that spacecraft; examples are IRAS and SOHO.

Prior to 1995 a comet would generally be assigned a name when its discovery was announced, but since then the names are assigned later by a committee chartered by the IAU for this task. Among other things, this allows for any belated discovery claims to be analyzed. While each situation may have its own peculiar details, in general, if the person "on duty" for a survey program clearly recognizes a comet as such, it will receive that person's name, otherwise, it will receive the program name. There has also been a conscious effort by the IAU to limit the names on a comet to two, although sometimes circumstances necessitate a third name; for example, in November 2018 amateur astronomer Don Machholz in California visually discovered a comet, which a few hours later was independently discovered by two Japanese amateur astronomers, Shigehisa Fujikawa and Masayuki Iwamoto, who were utilizing CCDs; the comet – which was formally designated C/2018 V1 – was named Machholz-Fujikawa-Iwamoto.



Discovery image of the moon S/2003 S 1 = Saturn XXXI, now named Narvi, taken February 5, 2003 by Scott Sheppard and colleagues with the 8.2-meter Subaru Telescope at Mauna Kea Observatory in Hawaii. Courtesy NASA.

Sometimes a periodic comet is discovered, then "lost," and then re-discovered again at a future return. Until 1995, when a comet would receive its name upon discovery, this would usually necessitate the comet's receiving both names once the identity was determined. Since then, the IAU committee will usually not assign a name until checks for possible identities with previous returns have been performed; if such a check turns up positive, the practice has been not to assign the comet the name of the discoverer on the recent return but rather to keep only the name of the discoverer from the earlier return.

It is not unusual for a discoverer – either individual or team – to discover two or more periodic comets. Prior to 1995, such comets would be assigned sequential numbers to differentiate between them at future returns; for example, Comet Wild 1, Comet Wild 2, etc., Comet Shoemaker-Levy 1, Comet Shoemaker-Levy 2, etc. (Again, these were only assigned to the periodic comets, not to any long-period comets that the discoverer(s) might have found.) With the new scheme implemented in 1995 and the sequential numbers assigned to all periodic comets, this practice was no longer necessary to differentiate between periodic comets, and thus it has been discontinued. In fact, it has been argued that the periodic comet numbers alone can serve as sufficient for identification, and officially the earlier-assigned numbers are no longer utilized; for example, Comet Wild 1 is now officially 63P/Wild (and not 63P/Wild 1), Comet Wild 2 is now officially 81P/Wild and not 81P/Wild 2, and so on. For my purposes here in "Ice and Stone 2020" I am keeping the earlier-assigned numerals; the Week 1 "Comet of the Week" can be called either 81P/Wild or 81P/Wild 2; I called it the latter, although formally it is referred to as the former.

Especially with the advent of the comprehensive surveys, in which more and more comets are being discovered by and assigned the names of those surveys, the IAU has wished to de-emphasize the importance of the names. (With even more comprehensive surveys expected to become operational within the not-too-distant future, the rationale for this should continue to become more apparent.) The formal practice of the IAU is to make the discovery designation of a comet the primary means of identifying it, with its name being added parenthetically; for example, the comet that bears my name is known officially as:

Comet C/1995 O1 (Hale-Bopp)

For my purposes here in "Ice and Stone 2020" I am elevating the importance of the name to being equal to that of the discovery designation, and am reversing the order, for example:

Comet Hale-Bopp C/1995 O1

While "small bodies of the solar system" usually refers to asteroids and comets, the moons of the planets – and, in particular, the smaller moons that may actually be "captured" asteroids and/or comets – as well as the moons of individual asteroids, are also "small bodies." They will, in fact, be covered in some detail in a future "Special Topics" presentation.

The current designation scheme for newly-discovered moons was implemented in 1978, although it has undergone some minor modifications since then. At present, the scheme for moons of major planets follows the following format:

S/<year>space<one-letter abbreviation of planet>space<number>

As with asteroids and comets, the "year" is the year of discovery, and the number is the sequential order of discovery (around a particular planet) that year. The one-letter abbreviations are, as one would expect, "J" for Jupiter, "S" for Saturn, "U" for Uranus, and "N" for Neptune. For example, if a moon around Jupiter were to be discovered this year, it would be designated S/2020 J 1, and if two moons were to be discovered around Saturn, the first would be S/2020 S 1 and the second would be S/2020 S 2.

Once a moon has been observed sufficiently well such that its orbit is well-determined and that it will no longer be "lost," it can be assigned a permanent designation. (Sometimes, as in the case with asteroids, this orbit-determination process may involve objects discovered in earlier years but subsequently "lost.") This permanent designation has the form:

<Planet>space<Roman numeral>

The Roman numerals are sequential. At this time, Jupiter has 72 moons that have been so numbered, and seven moons that are "lost;" if and when any of those are re-discovered or an as-yet-undiscovered moon is found and observed well enough for a valid orbit determination, it would be designated Jupiter LXXIII. For what it's worth, at this time Saturn has 53 formally-designated moons (with over 30 more – many of which were just announced late last year – awaiting confirmation or recovery), Uranus has 27, and Neptune has 14.

For the most part, names have been assigned to moons in keeping with their respective parent planet. Jupiter's moons have usually been named for descendants of the mythological Greek god Zeus, Saturn's moons have usually been named for the Greek

Main-belt asteroid (243) Ida and its moon Dactyl (at right), photographed August 28, 1993 by the Galileo spacecraft. Image courtesy NASA/JPL.

Titans and their descendants, and Neptune's moons have been assigned the names of Greek water deities. Following the precedent set by William Herschel, who discovered not only Uranus but also its first two known moons (Titania and Oberon), Uranus' moons are usually assigned names out of the plays of William Shakespeare. With the advent of modern imaging technology which, in theory, can allow for very tiny moons to be discovered, the IAU has been discouraging the assigning of names to more recently-discovered moons, although a few have nevertheless been assigned.

The designations for moons of asteroids follows the same basic scheme, with the exception that an asteroid's formal sequential number is used instead of the first letter of its name. The first-known asteroid moon to be designated was found (by the Galileo spacecraft) around the main-belt asteroid (243) Ida, and was designated (in the current scheme) as S/1993 (243) 1, and the moon around the near-Earth asteroid (65803) Didymos (the destination of the forthcoming DART mission, which was discussed in the "Special Topics" presentation two weeks ago) was designated S/2003 (65803) 1. Formally, these moons are now designated (243) Ida I and (68503) Didymos I.

Although only a handful of asteroidal moons have been formally named, in general those that have been have followed the precedent established by moons of the major planets, i.e., some association with the name of their parent body. For example, Ida's moon has been named Dactyl, after the creatures that inhabited the mythological Mount Ida. Didymos' moon has not received a formal name at this time, although it is informally known as "Didymoon;" perhaps it might receive a formal name by the time DART arrives.

GLOSSARY

I hope you are enjoying reading the weekly Ice and Stone 2020 content. For those who might not be as versed in astronomy terms, I've put together this glossary of technical terms, many of which are regularly used within these Ice and Stone 2020 educational presentations.

ABSOLUTE MAGNITUDE: for a comet or asteroid, the apparent magnitude it would have if it were located 1 AU from both the earth and the sun (and, for an asteroid, at a phase angle of zero degrees).

ALBEDO: the measure of the "reflectivity" of an object, usually expressed as a decimal fraction (the amount of light reflected divided by the amount of light received). Objects with a low albedo are "dark," and those with a high albedo are "bright."

"ANNUAL" COMET: a periodic comet which, because of its small orbit and/or modern observational techniques, is observable throughout its entire orbit.

ANTI-TAIL: an apparent sunward-pointing tail of a comet, in actuality a geometrical effect caused by the scattering of sunlight by dust grains within the plane of the comet's orbit.

APHELION: that point in an object's orbit which is farthest from the sun.

APOLLO-TYPE ASTEROID: an asteroid whose orbit brings it to within the earth's orbit (i.e., its perihelion distance is less than 1 AU).

APPARENT MAGNITUDE: the magnitude of an object that is measured from the earth (or wherever the observer is located).

APPARITION: the passage of a comet through the inner solar system, specifically the period of time around its perihelion passage. For a periodic comet, "apparition" is synonymous with "return."

ARCMINUTE: 1/60 of a degree.

ARCSECOND: 1/60 of an arcminute.

ASTEROID BELT: The region of the solar system, between the orbits of Mars and Jupiter, wherein the majority of the asteroids orbit the sun. This is sometimes referred to as the "main belt."

ASTROMETRY: the practice of measuring precise and accurate coordinates of objects (usually comets and asteroids) on the celestial sphere, primarily for usage in calculation of the orbital elements.

ASTRONOMICAL UNIT (AU): a unit of distance equivalent to the average distance between the earth and the sun (93 million miles, or 149 million km). The distances of objects within the solar system are usually expressed in AU.

BROWNLEE PARTICLES: very tiny, porous dust grains that have been collected in the earth's upper atmosphere, and believed to be the same type of dust grains that make up cometary comae and dust tails.

CELESTIAL SPHERE: the sky as seen from the earth's surface, imagined as being projected upon the inside surface of a sphere that encircles the earth. Positions upon the celestial sphere can be described via the coordinates of right ascension and declination, which are analogous to the coordinates of longitude and latitude used on the earth's surface.

CENTAURS: objects, which may be asteroids and/or comets, which travel in orbits that remain in the general vicinity of the outer planets (i.e., Jupiter to Neptune).

CENTRAL CONDENSATION: a dense cloud of material surrounding a comet's nucleus, and which usually appears as a bright spot within the coma.

CHARGE COUPLED DEVICES (CCDS): electronic imaging systems which utilize a computer chip to convert received light into electrical charges, and then store this information as a computer-readable image.

COMA: the "fuzzy" head of a comet, composed of gas and dust which has been ejected off the nucleus as it approaches the sun.

CONJUNCTION: literally, a meeting or close gathering of two or more objects. When applied to astronomical objects, the term usually means that the two objects are located along the same line of sight as seen from the earth. Unless specifically indicated otherwise, an object which is stated as being "in conjunction" is usually understood as being in conjunction with the sun.

CORONA: the faint, tenuous (but hot) outer atmosphere of the sun, usually visible only during a total solar eclipse or via the use of a coronagraph.

CORONAGRAPH: a device (either on the ground or aboard a spacecraft) which utilizes a central opaque "occulting disk" to block out the light of the sun and create an artificial solar eclipse, in turn allowing the sun's corona and objects within the sun's immediate vicinity to be detected.

DECLINATION: the coordinate used on the celestial sphere which is analogous to the terrestrial coordinate of latitude.

DEGREE: a unit of angular measure, equal to 1/360 of a full circle. Sizes of objects in the sky, and distances between them, are usually expressed in degrees.

"DIRTY SNOWBALL" (MORE FORMALLY, THE "ICY CONGLOMERATE"): the theory originally put forth by Fred Whipple in 1950 concerning the structure of a comet's nucleus, which was verified when the Giotto spacecraft flew by the nucleus of Comet P/Halley in 1986.

DISCONNECTION EVENT: a "break" or disconnection in a comet's ion tail, generally believed to be caused by changes in the solar wind and/or variations in the interaction between the solar wind and the comet's magnetic environment.

DUST TAIL: the tail of a comet that is composed primarily of dust grains that have been ejected off the nucleus.

ECCENTRICITY (E): a measure of how elongated an orbit is. Orbits with an e of 0 are circles; those with e between 0 and 1 are ellipses; those with an e of 1 are parabolas, and those with e greater than 1 are hyperbolas.

ECLIPTIC: the path across the constellations upon which the sun travels.

ELECTROMAGNETIC SPECTRUM: a term that encompasses all the various forms of light which can be given off by means of physical processes and which can (in theory, at least) be detected with scientific instruments. On the high-energy, high-frequency, short-wavelength end of the electromagnetic spectrum are gamma rays; proceeding "downward" to lower energies, lower frequencies, and longer wavelengths are x-rays, ultraviolet, "visible" light, infrared, microwaves, and radio waves.

ELEMENTS: the mathematical quantities which define the parameters of an object's orbit around another object, for example, a comet's orbit around the sun. These elements include the date and location of perihelion, the inclination of its orbit with respect to Earth's orbit, etc.

ELLIPSE: an oval-shaped closed curve. The orbits of all planets, asteroids, and (most) comets around the sun are ellipses. The ellipses within which the planets and most of the asteroids travel are nearly circular, whereas most comets travel in orbits which are far more "elliptical."

ELONGATION: the angular separation (in degrees) between an object on the celestial sphere and the sun, as seen from the earth.

EPHEMERIS (PLURAL EPHEMERIDES): a table listing an object's position in the sky (usually its right ascension and declination) on different dates. The ephemeris for an object like a comet is computed from its orbital elements.

"FLYING SANDBANK": a now-discredited theory of a cometary nucleus first proposed during the 19th Century wherein the nucleus was postulated as being composed of a large number of loosely-bound dust particles of sizes up to perhaps a few meters in diameter.

GAS TAIL: see "ion tail" below.

HALLEY-TYPE COMET: a comet normally with an orbital period between 20 and 200 years. Most Halley-type comets have orbital inclinations and eccentricities that are significantly larger than those of Jupiter-family comets.

HYPERBOLA: a large open-ended curve; an object traveling in a hyperbolic orbit will never return to the object it is orbiting.

"ICY CONGLOMERATE": see "dirty snowball" above.

INCLINATION: a measure of how much an orbit is tilted with respect to the earth's orbit, usually expressed in degrees. An orbit with an inclination less than 90 degrees is said to be "prograde," or "direct," whereas an orbit with an inclination greater than 90 degrees is said to be "retrograde."

INTRINSIC BRIGHTNESS: when referring to a comet, the brightness that that comet exhibits as a result of its own size and activity, without regard for any external factors, such as its distance from the sun or the earth. This is often quantified through the use of a comet's "absolute magnitude."

IONIZED: electrically charged. Specifically, an atom that has been ionized either has had negatively-charged electrons stripped from it, resulting in a positive ion, or has extra electrons added to it, resulting in a negative ion.

ION TAIL: the tail of a comet that is composed of gas molecules that have been ejected off the nucleus and then ionized by the solar wind. Also called the "gas tail" or the "plasma tail."

JET: an emission of material off a comet's nucleus, similar to the eruption of a geyser.

JUPITER-FAMILY COMET: a comet that has been "captured" by Jupiter's gravity into a very small short-period orbit. Most Jupiter-family comets have orbital periods of six to eight years and relatively small orbital inclinations.

KREUTZ SUNGRAZER: one of a "family" of comets first extensively studied by Heinrich Kreutz during the late 19th Century which are characterized by very similar orbits and extremely small perihelion distances, usually less than 0.01 AU.

K-T EVENT: the supposed impact of a comet or asteroid onto the earth at the end of the Cretaceous Period 65 million years ago, and believed to be responsible for the extinction of the dinosaurs and many other species living at that time.

KUIPER BELT: a broad band of objects (comets and/or asteroids) orbiting the sun at distances between 30 AU and a few hundred AU.

LAGRANGIAN POINT: one of five points in a two-body gravitational system where the gravitational attractions from the two bodies are equal. In the absence of any perturbing bodies these points can be considered as being very stable.

LONG-PERIOD COMET: by definition, a comet with an orbital period of greater than 200 years.

MAGNITUDE: the scheme currently used to describe the brightness of an astronomical object. The brighter an object, the smaller is its magnitude number, and the fainter an object, the larger is its magnitude.

METEOR SHOWER: those occasions when the earth intersects a stream of interplanetary dust particles, creating the effect that numerous meteors appear to emanate from the same location in the sky.

NEAR-EARTH ASTEROID: an asteroid that can come relatively close to the earth; primarily used to indicate those with perihelion distances less than approximately 1.2 AU.

NODE: the point in an object's orbit where it crosses the plane of the earth's orbit. The "ascending node" is where the object crosses the plane from south to north, and the "descending node" is where it crosses from north to south.

NON-GRAVITATIONAL FORCES: small changes in a comet's orbital motion, caused by the eruptions of material off the nucleus. These eruptions act as small rocket engines, and can cause a comet to deviate slightly from its predicted course.

NUCLEUS: the "solid" object in the center of a comet. A comet's nucleus is composed primarily of dust mixed in with various ices, and when it approaches the sun, the sun's heat causes the ices to sublimate, creating the coma and the tail.

OCCULTATION: an event wherein one solar system object (e.g., the moon or a planet) passes in front of a more distant object, as seen from our vantage point on the earth.

OORT CLOUD: a large, spherical cloud of comets believed to enshroud the solar system at distances of 1000 to 10,000 AU.

OPPOSITION: located in a position in the sky opposite to that of the sun. A solar system object at opposition will usually rise around sunset, be at its highest point above the horizon around midnight, and will set around sunrise.

ORGANIC MOLECULES: complex molecules composed of chains of carbon atoms, upon which are attached atoms of various other elements. Organic molecules form the basis for all known life forms, although the presence of such molecules in an environment does not necessarily imply the presence of life.

OUTBURST: a sudden, dramatic (and usually short-lived) increase in a comet's brightness.

OUTGASSING: when applied to a comet, the release of gas and dust from the nucleus through sublimation.

PARABOLA: an open-ended curve; an object traveling in a parabolic orbit will never return to the object it is orbiting. Most long-period comets have orbits which are close to being parabolas.

PERIHELION: that point in an object's orbit that is closest to the sun.

PERIODIC COMET: see "short-period comet" below.

PERTURBATIONS: disturbances of an object's orbit as a result of gravitational forces from other objects.

PHA: "Potentially Hazardous Asteroid." By definition, an asteroid larger than 100 to 200 meters in diameter which can approach to within 0.05 AU of the earth's orbit.

PHASE: the angular separation between the earth and sun, as viewed from the object in question. For a solid object like an asteroid, there is an inverse correlation between its phase angle and the fraction of its sunlit surface that is visible from Earth.

PHOTOMETRY: the practice of measuring the brightness, or magnitude, of an astronomical object.

PLANETESIMAL: one of the "building blocks" that formed the planets during the early stages of the solar system. Leftover planetesimals became the objects we know today as comets and asteroids.

PLASMA TAIL: see "ion tail" above.

POLYMER: A relatively large, complex molecule, formed by linking chains of smaller, simpler molecules.

PRECESSION: the "wobbling" motion of a rotating object caused by an external gravitational field. The earth's precessional cycle takes approximately 25,800 years to complete one "wobble."

PRE-DISCOVERY (PHOTOGRAPH): a photograph of a comet (or other object) taken before that object's discovery, but not noticed until after the discovery has been reported. Often these images are found as a result of a deliberate search after an object's orbit has been computed.

RADIANT: the point in the sky from which the meteors in a meteor shower appear to radiate.

"RESISTING MEDIUM": a now-discredited idea proposed in the 19th Century to explain what is now called non-gravitational forces, wherein interplanetary "material" that a comet encountered would act to slow it down into a smaller orbit.

RESONANCE: a condition wherein the ratio of the orbital periods of two objects is a simple fraction, e.g., 1:2, 2:3, etc.

RETROGRADE: moving in a direction opposite that of the earth (see "inclination" above).

RIGHT ASCENSION (RA): the coordinate used on the celestial sphere which is analogous to the terrestrial coordinate of longitude.

ROCHE RADIUS: the distance from an object (such as a planet) within which the tidal forces acting upon a smaller object (such as a comet) are stronger than the internal material strength of that smaller object, and thus it is ripped apart.

SEMI-MAJOR AXIS: half of the distance between an object's perihelion and aphelion points. This is also equivalent to an object's average distance from the sun.

SOLAR WIND: a stream of highly energetic charged particles (such as protons, electrons, and ions) constantly "blowing" off the sun's "surface."

SHORT-PERIOD COMET: by definition, a comet with an orbital period of 200 years or less.

SPECTROPHOTOMETRY: the practice of measuring an object's brightness at different wavelengths in the electromagnetic spectrum, and combining these to produce its spectrum.

SPECTROSCOPY: The practice of observing and recording an object's spectrum.

SUBLIMATE: to change directly from a solid to a gas. Substances such as water and carbon monoxide ice do this in space when they are heated, since the vacuum around them does not "force" them into a liquid state.

SUNGRAZER: see "Kreutz sungrazer" above.

SYNCHRONIC BANDS: parallel ray-like structures in a comet's dust tail, believed to be caused by the disruption of large dust grains.

TRANS-NEPTUNIAN OBJECTS (TNOS): an alternative name given for objects which inhabit the Kuiper Belt.

VOLATILE: a substance that is highly reactive and/or undergoes reactions or other changes as a result of only mild stimuli (e.g., temperatures, etc.)

ZODIAC: the group of constellations within which the sun, moon, and planets travel.

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