ICE & STONE 2020

WEEK 45: NOVEMBER 1-7

Presented by The Earthrise Institute

#45

Authored by Alan Hale

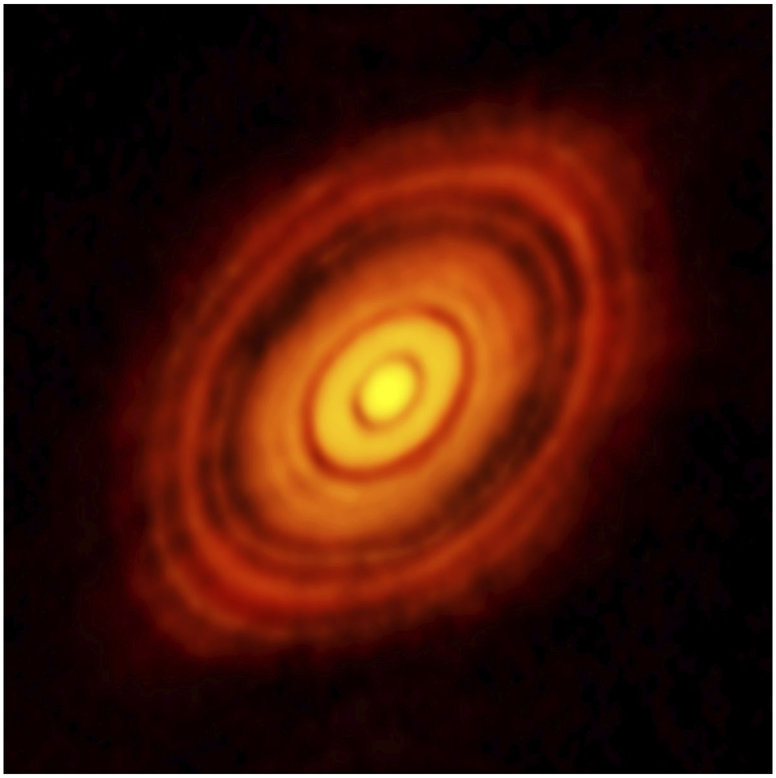
THIS WEEK IN HISTORY

NOVEMBER 1 | 2 | 3 | 4 | 5 | 6 | 7

NOVEMBER 1, 1577: Observers in Peru make the first sighting of the Great Comet of 1577. This comet, a brilliant object which is often referred to as "Tycho Brahe's Comet" and which is one of the most important scientific comets in history, is next week's "Comet of the Week."

NOVEMBER 1, 1948: Observers on the ground near Nairobi, Kenya, as well as in a Royal Air Force plane flying at 4000 meters, detect a bright comet near the sun during a total solar eclipse. The Eclipse Comet of 1948 and other "eclipse comets" are the subject of a previous "Special Topics" presentation.

NOVEMBER 1, 1975: University of California astronomer Martin Cohen publishes a paper announcing the likely presence of water ice surrounding the young solar-type star HL Tauri. A protoplanetary disk has since been detected surrounding this star. The significance of Cohen's discovery is discussed in a previous "Special Topics" presentation.



The protoplanetary disc surrounding the young star HL Tauri is seen in this sharp image from the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile. It reveal substructures within the disc that have never been seen before and even show the possible positions of planets forming in the dark patches within the system. Courtesy ALMA (ESO/NAOJ/NRAO).

NOVEMBER 1, 1998: A team led by William Merline discovers a moon, since named Petit-Prince, around the main-belt asteroid (45) Eugenia with the Canada-France-Hawaii Telescope at Mauna Kea. This was the first asteroid moon to be discovered with a ground-based telescope, and only the second asteroid moon ever to be discovered. A second moon around Eugenia was discovered in 2004. Asteroid moons are the subject of a previous "Special Topics" presentation.

NOVEMBER 1, 2020: The main-belt asteroid (149) Medusa will occult the 7th-magnitude star HD 69072 in Cancer. The predicted path of the occultation crosses northern India, central Tibet, central China, southern North Korea, northern South Korea, and the northern part of the Japanese island of Honshu.

NOVEMBER 2

NOVEMBER 2, 1980: MIT student Paul Kamoun detects the nucleus of Comet 2P/Encke with radar signals utilizing the 300-meter radio telescope at Arecibo, Puerto Rico. This was the first successful detection of a cometary nucleus via radar. Comet 2P/Encke returned to perihelion earlier this year and is a previous "Comet of the Week."

NOVEMBER 2, 2002: NASA's Stardust mission flies by the main-belt asteroid (5335) Annefrank while en route to Comet 81P/Wild 2. The Stardust mission is discussed in a previous "Special Topics" presentation.

NOVEMBER 2, 2020: The very tiny near-Earth asteroid 2018 VP1, discovered two years ago by the Zwicky Transient Facility program in California, is expected to make a close flyby of Earth. The asteroid has not been seen in two years and is approaching Earth from the general direction of the sun, and thus the exact circumstances of this encounter are uncertain; the nominal "miss distance" is 0.0021 AU (314,000 km, or 0.8 lunar distances).

NOVEMBER 2, 2021: Comet 67P/Churyumov-Gerasimenko will pass through perihelion at a heliocentric distance of 1.211 AU. During its previous return in 2015 Comet 67P was the destination of ESA's Rosetta mission, and it is a previous "Comet of the Week."

NOVEMBER 3

NOVEMBER 3, 2020: The main-belt asteroid (519) Sylvania will occult the 7th-magnitude star HD 47255 in Auriga. The predicted path of the occultation crosses south to north across east-central Australia, the province of Papua in Indonesia on the western half of the island of New Guinea, far southwestern South Korea, northeastern China, far northeastern Mongolia, central Russia, western Belarus, and southeastern Poland.

NOVEMBER 4

NOVEMBER 4, 2010: NASA's EPOXI mission flies by Comet 103P/Hartley 2. EPOXI, retooled from the earlier Deep Impact mission, is discussed in a previous "Special Topics" presentation.

1 2 3 4 **NOVEMBER 5** 6 7

NOVEMBER 5, 2005: Images taken with the Canada-France-Hawaii Telescope at Mauna Kea Observatory in Hawaii contain pre-discovery images of Comet Boattini C/2010 U3, which was discovered in October 2010 (during the course of the Mt. Lemmon survey in Arizona) and which passed through perihelion (at a heliocentric distance of 8.45 AU) in February 2019. At the time these images were taken the comet's heliocentric distance was 25.751 AU, the largest heliocentric distance at which an incoming long-period comet has ever been detected.

NOVEMBER 5, 2012: Astronomers Scott Sheppard and Chad Trujillo discover the "asteroid" 2012 VP113 from Cerro Tololo Inter-American Observatory in Chile. This was the second known object, after (90377) Sedna, to exist entirely within the far outer solar system, and these objects are discussed in next week's "Special Topics" presentation.

NOVEMBER 5, 2020: The Amor-type asteroid (433) Eros will pass through perihelion at a heliocentric distance of 1.133 AU. It is currently in the morning sky, traveling east-southeastward through the constellation Leo, and is around 13th magnitude. Eros was the first-known near-Earth asteroid and is the subject of a previous "Special Topics" presentation.

1 2 3 4 5 **NOVEMBER 6** 7

NOVEMBER 6, 1892: An amateur astronomer in London, Edwin Holmes, discovers a bright comet located near the Andromeda Galaxy. This comet, now known as Comet 17P/Holmes, has undergone the largest cometary outbursts ever recorded, and is this week's "Comet of the Week."

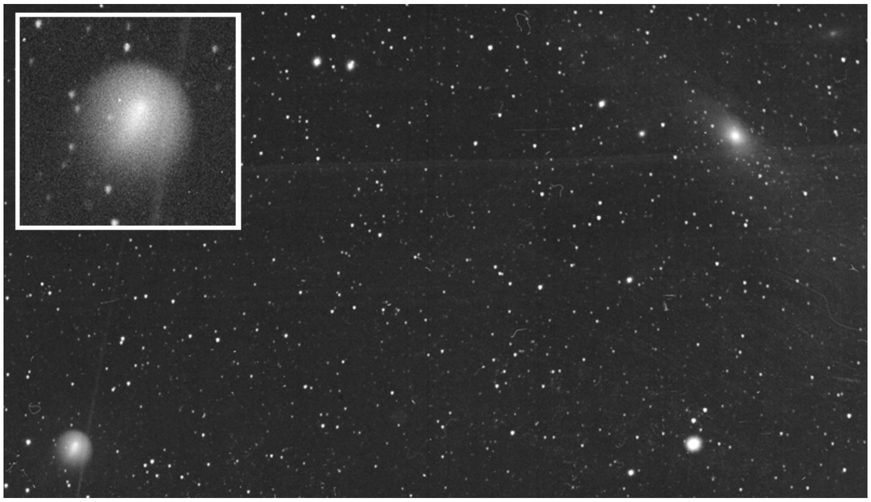
1 2 3 4 5 6 **NOVEMBER 7**

NOVEMBER 7, 1882: The Director of the Cape Observatory in South Africa, David Gill, takes a 100-minute exposure of the Great Comet of 1882 (a previous "Comet of the Week"). Not only was this the first "good" photograph of a comet, it showed so many stars that it started a paradigm shift among astronomers regarding the usefulness of astro-photography, and among other things stimulated the first major international collaborative astronomical projects.

NOVEMBER 7, 2018: Amateur astronomer Don Machholz in California visually discovers a 10th-magnitude comet, which is independently discovered later that same morning by two Japanese amateur astronomers (Shigehisa Fujikawa and Masayuki Iwamoto), both of whom were utilizing CCDs. Comet Machholz-Fujikawa-Iwamoto C/2018 V1 was the first comet to be discovered visually in eight years and is the last one to be so discovered as of now; it is conceivable that it may be the last comet ever to be discovered visually.

COMET OF THE WEEK: 17P/HOLMES

Perihelion: 2007 May 4.50, q = 2.053 AU



Comet 17P/Holmes and the Andromeda Galaxy M31 in 1892 following its discovery. Left: Photograph taken on November 10 by Edward Barnard at Lick Observatory in California. Courtesy UCO/Lick Observatory. Right: Photograph taken on November 14 by Max Wolf at Konigstuhl Observatory in Heidelberg, Germany.

With the light pollution that is endemic to large metropolitan areas, it would seem difficult to believe that any significant astronomical observational activities could be conducted from cities like London these days. But things were different during the late 19th Century . . . On the evening of November 6, 1892, an amateur astronomer in London, Edwin Holmes, was finishing up a night of observations when he decided to finish by taking a look at the Andromeda Galaxy M31. Nearby he happened across a similarly bright (4th magnitude) diffuse object a few arcminutes across . . . which turned out to be a previously-unknown comet.

The sudden appearance of such a bright comet in such a well-observed part of the sky was initially a mystery, but it soon became clear that Holmes' comet had undergone a massive outburst, presumably of several magnitudes, shortly before its discovery. For the next few weeks it maintained this overall brightness, but the coma expanded dramatically, until shortly before the end of November it was close to 30 arcminutes across. After that it began a rapid fading, and by the end of the year it was close to 10th magnitude, however in mid-January 1893 it underwent another outburst of at least five magnitudes, again achieving naked-eye visibility as a 5th magnitude object, and after which it was observed to be changing its appearance on an hour-to-hour basis. Afterwards it faded again, and the final observations were obtained in early April.

Spectroscopic observations made of the comet while it was in outburst indicated that the coma was composed almost entirely of dust.

Holmes' comet was found to be periodic, with an orbital period of close to seven years. It was duly recovered in 1899 but remained faint, never getting brighter than 13th magnitude, and was even fainter in 1906, when it only reached 15th magnitude and was only photographed on a handful of occasions. After that it was missed on the next several subsequent returns, and the general consensus was that it had disintegrated – the major outbursts in 1892-93 perhaps having been its death throes. However, in his landmark 1963 study on "lost" periodic comets – already mentioned in the "Comet of the Week" Presentation of Comet 9P/Tempel 1 – then-Yale University graduate student Brian Marsden analyzed the motion of Comet Holmes, and determined that it should be returning to perihelion in November 1964. Elizabeth Roemer, then at the U.S. Naval Observatory's station in Flagstaff, Arizona, successfully photographed it in July and September of that year as a very faint object of 19th magnitude, verifying that the comet indeed still existed.

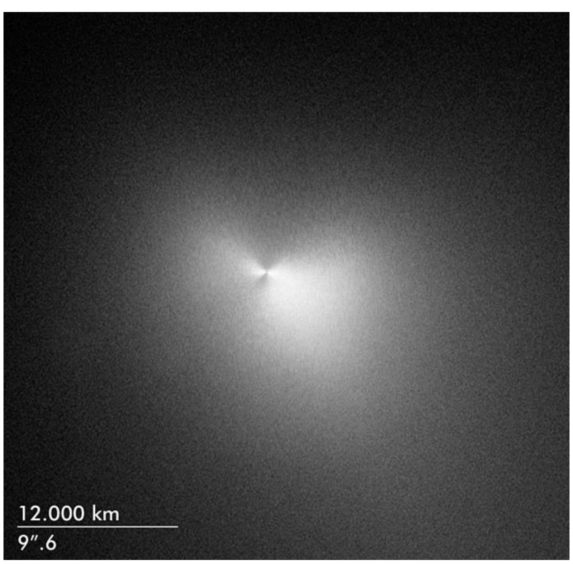
Comet Holmes was duly recovered at each of the next several subsequent returns, and remained a


The early stages of Comet Holmes' 2007 outburst. Left: image taken on October 24 – shortly after the outburst began – by Ernesto Guido and Giovanni Sostero in Italy, utilizing a remotely-controlled telescope in New Mexico. Right: The comet on October 29. Courtesy Mike Holloway in Arkansas.

faint and entirely unremarkable object never getting any brighter than 17th or 18th magnitude. When it was recovered in May 2007 around the time of that return's perihelion passage it was somewhat brighter, around 15th magnitude, but faded steadily from that point, and by September and October was back around 17th magnitude.

On October 24 a Spanish astronomer from near Tenerife in the Canary Islands, Juan Antonio Henriquez Santana, reported that the comet was apparently undergoing a massive outburst and was close to 8th magnitude, which was quickly verified by other Spanish observers (who reported it as having brightened to 7th magnitude). After reading their report a few hours later I observed it as a star-like object of 4th magnitude, and within about half a day it had reached close to its peak brightness of almost 2nd magnitude. It was obvious that the comet was experiencing an outburst similar to that of 1892, and the overall brightness change of almost 15 magnitudes, corresponding to an increase in brightness by a factor of approximately 600,000, is the largest cometary outburst ever recorded.

The evolution of the new outburst was similar to that of 1892; within a week the comet appeared as a dense inner coma about 15 arcminutes across enshrouded within a dimmer outer "halo" half a degree in diameter, and within another week this "halo" was almost a full degree across. By December this "halo" had all but dispersed, however the inner



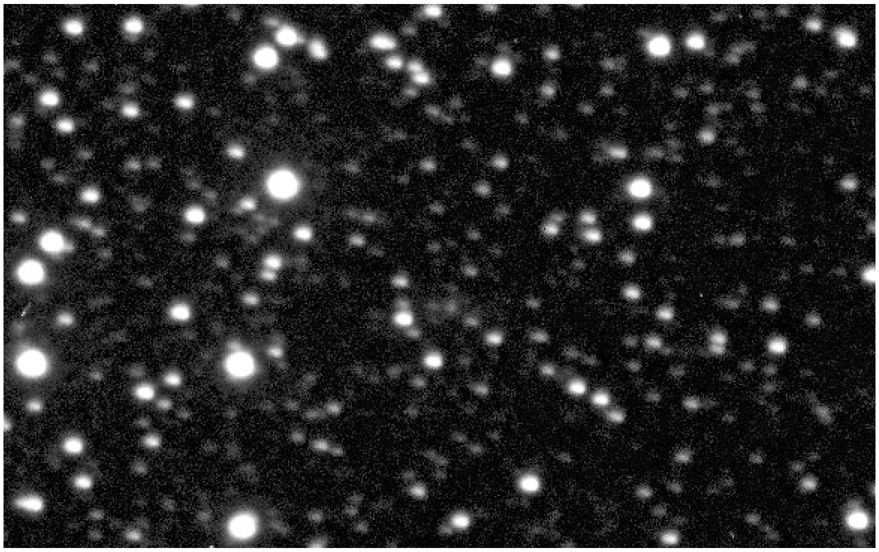
Left: The inner coma of Comet Holmes on November 4, 2007, as imaged by the Hubble Space Telescope. Courtesy NASA. Right: A wide-field image of Comet Holmes I took on the evening of December 2, 2007. The Alpha Persei Cluster (Melotte 20) is below the comet.

coma itself expanded, being over a degree across by late in the year. The comet itself slowly faded, being close to 4th magnitude in late December and 5th magnitude in March 2008, by which time the coma was only dimly detectable to the unaided eye as a pale diffuse cloud about 80 arcminutes in diameter. The entire comet exhibited numerous features over both large scales and small scales, from strong jets off the nucleus that were visible in images taken with the Hubble Space Telescope, to "streamers" within the coma which itself took on a "bow in a wake" appearance, and to faint streams of an ion tail, which was mostly directed away from Earth.

Several possible explanations for Comet Holmes' outburst activity have been proposed. One of these held that the 2007 outburst might have been due to a companion nucleus being jettisoned from the primary nucleus and then undergoing a "cataclysmic" disintegration. Another explanation proposed that the outburst was due to an airtight dust cover over the nucleus that was broken up by water sublimation going on underneath it. In truth, no explanation seems entirely satisfactory, given the unique nature of the outbursts in both 1892-3 and in 2007, and the fact that while other comets have clearly exhibited outbursts, those of Comet Holmes are pretty much in a class by themselves.

After the 2007 outburst subsided large telescopes continued to follow the comet, through its aphelion in late 2010. At its next return in 2014 (perihelion late March) it underwent a couple of small outbursts, to about magnitude 12½ in late May/early June and another one to about magnitude 14½ in late January 2015 – ten months after perihelion passage – but nothing close to what it underwent in 2007. It has now been picked up en route to its next perihelion passage on February 19, 2021 and, not unexpectedly, has thus far remained faint (currently about 17th magnitude). Meanwhile, it should be returning every seven years hereafter for at least the near-term foreseeable future; perhaps some day it may burst forth yet again in another major outburst, and maybe at that time we might be able to determine just what is causing this bizarre behavior.

Later stages of Comet Holmes' 2007 outburst. Above: The comet on November 28, 2007. The coma's parabolic shape and the "wake"-like structure in the inner coma are prominent. Below: Comet Holmes and the California Nebula (NGC 1499) on the evening of March 4, 2008. Both images courtesy Mike Holloway in Arkansas.



Comet 17P/Holmes (small, diffuse object in center) on its current return. I took this image on October 20, 2020 via the Las Cumbres Observatory facility at Siding Spring Observatory in New South Wales.

SPECIAL TOPIC: THE DEATH OF COMETS

What happens to comets when they "die?" Our solar system has been around for 4.6 billion years, and, obviously, a large percentage of the comets that the solar system started off with are no longer with us. While many comets still remain in the reservoirs of the outer solar system, i.e., the Kuiper Belt and the Oort Cloud, once they begin making passages into the inner solar system and start becoming active their days, so to speak, are numbered. As it turns out, there are several mechanisms by which comets can meet their demise.

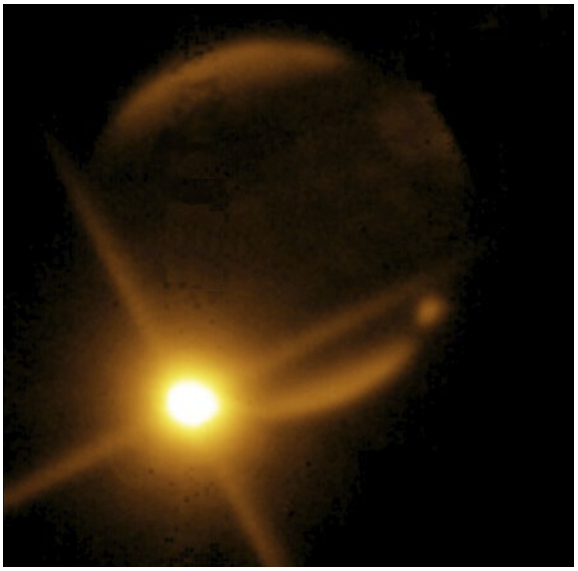
An interstellar exile. I took this image of Comet 2I/Borisov on December 21, 2019 with the Las Cumbres Observatory facility at McDonald Observatory in Texas.

Many comets do not "die" but rather are ejected from the solar system and thus "exiled" into interstellar space. As discussed in previous "Special Topics" presentations, the comets that were initially kicked out into the Oort Cloud are only loosely held to the solar system, and passing stars and tidal forces from the overall Galaxy can either perturb comets into the inner solar system or eject them from the solar system completely, and it is likely that there are far more of the latter than there are the former. Comets that pass by the major planets, especially Jupiter, can also be perturbed into hyperbolic orbits and consequently ejected from the solar system, and this has in fact been observed on numerous occasions.

Any such exiled comet would roam through the Galaxy essentially forever. On occasion, such as with the interstellar Comet 2I/Borisov last year – a previous "Comet of the Week" – it might encounter another planetary system and pass through it, but after doing so it would once again head back out into the Galaxy and continue its wanderings.

Some comets will meet a much more dramatic demise by impacting another object, and this has undoubtedly occurred many times throughout the solar system's history. We have seen this once, in July 1994 when Comet Shoemaker-Levy 9 1993e – another previous "Comet of the Week" – impacted Jupiter. Earth has also certainly been impacted by comets from time to time, although hopefully this will not happen anytime within humanity's near- to intermediate term future, and in the unlikely event that a threatening object were to be inbound the presently-operating survey programs should give us a long enough advance warming to take appropriate action, as discussed in previous "Special Topics" presentations.

Comets, being made up of various ices, are rather porous objects to begin with, and as they make repeated passages through perihelion they continuously lose a fraction of their material. Eventually, so much material is lost that there is really nothing left, and the comet essentially just "disappears." Even through the half-century that I have been following comets there have been several periodic comets that have simply vanished and that are no longer making returns.



A comet destroyed by impact. This is an infrared image of the impact of nucleus "G" of Comet Shoemaker-Levy 9 into Jupiter on July 18, 1994, taken by Peter McGregor from Siding Spring Observatory in New South Wales. Image courtesy Mount Stromlo and Siding Spring Observatories.

Sometimes this disintegration process is accompanied by a fragmenting of the nucleus. A classic example of this is Comet 3D/Biela – a previous "Comet of the Week" – which, after being observed during several returns in the late 18th and early 19th Centuries, appeared as a "double comet" for two returns and then just vanished – with the exception of strong meteor showers that occurred for a few returns thereafter. Although not quite as dramatic as this, there have been a couple of more recent cases where a periodic comet has been observed to fragment and then subsequently vanish. Since the fragmenting of a comet's nucleus will expose previously-hidden ice to sunlight which will then start undergoing new activity, these fragmenting events are often associated with outbursts in brightness. Indeed, there have been a couple of recent cases where a short-period comet was discovered during an obvious outburst, and then disappeared after a few returns – or in a few cases was never seen again.

An image of a disintegrating comet: Comet SWAN C/2020 F8 on May 31, 2020, four days after its perihelion passage (heliocentric distance 0.43 AU). Courtesy Pierre Girard in England.

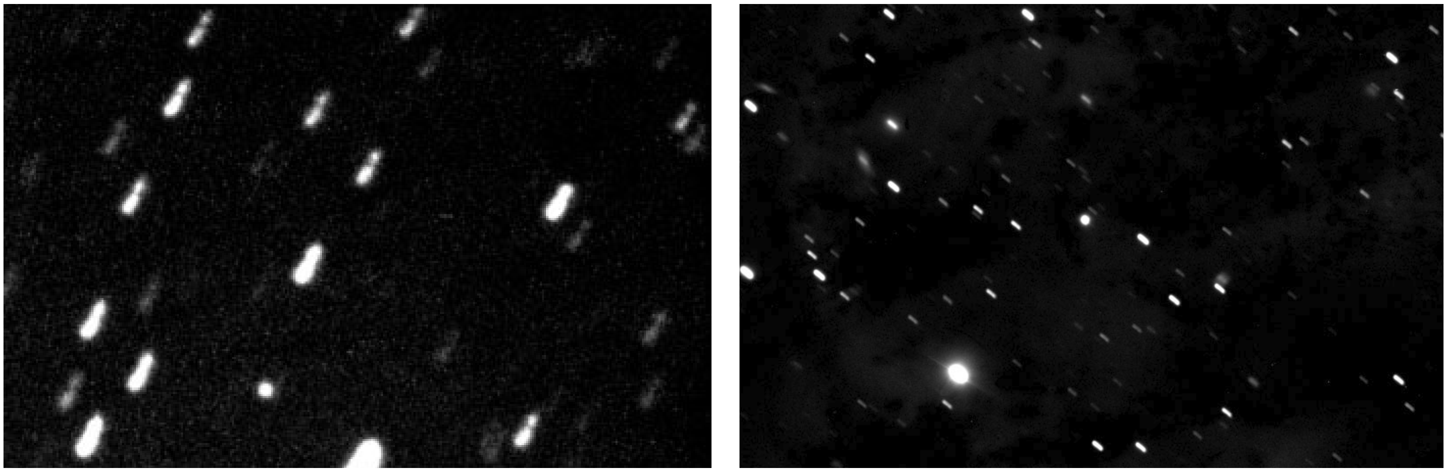
Many long-period comets also have been seen to disintegrate as they pass through perihelion. In general, the smaller a comet's perihelion distance – and thus the more intense solar heating it experiences – and the smaller the nucleus, the more likely it is that it will not survive perihelion. The small spacecraft-discovered Kreutz sungrazers – discussed in last week's "Special Topics" presentation – are a striking example of this. Over my years of observing comets there have been several that have proceeded towards perihelion – sometimes exhibiting outbursts as they do so – but then either didn't reappear after perihelion, or in some cases didn't even make it to perihelion at all. In 1991 veteran comet observer John Bortle developed an empirical formula that utilizes a long-period comet's perihelion distance and its absolute magnitude to predict whether or not it will survive perihelion: H_max = 7.0 +6q, where H_max is the limiting absolute magnitude for survival (and q, as always, is the perihelion distance in AU). While the exact physical relationship between a comet's absolute magnitude and the size of its nucleus is not something that can be firmly established, in general, the brighter the absolute magnitude, the larger the nucleus.

The tail remnant of Comet Elenin C/2010 X1 on October 22, 2011, as imaged by a remotely-controlled telescope in New Mexico. Courtesy Rolando Ligustri in Italy.

A recent dramatic example of a disintegrating long-period comet is Comet ISON C/2012 S1, which is a future "Comet of the Week." Another interesting recent example is Comet Elenin C/2010 X1, which passed through perihelion in September 2011 at a heliocentric distance of 0.48 AU. As the comet disappeared into twilight en route to perihelion it began to grow very diffuse, as if it was starting to disintegrate, and when it passed through perihelion and theoretically should have been detectable with the coronagraphs aboard the NASA/ESA SOlar and Heliospheric Observatory (SOHO) spacecraft there was nothing to be seen, despite the fact that there should have been a strong brightness enhancement due to forward scattering of sunlight. When Comet Elenin emerged into the morning sky in October initially nothing was seen, however once it climbed higher above the horizon CCD images began to show a thin wisp-like structure 10 to 20 arcminutes long. This was the comet's tail, apparently created by a dust ejection event just as the nucleus began to disintegrate; it survived, while the comet itself did not.

We have seen some recent examples of this phenomenon during "Ice and Stone 2020." As discussed in its own "Comet of the Week" Presentation, Comet ATLAS C/2019 Y4 began to disintegrate as it approached perihelion, and as it turned out nothing was seen afterwards. Comet SWAN C/2020 F8, discussed within that same Presentation, also began to show signs of disintegration, and by the time of perihelion passage was nothing more than a "smear" of light that disappeared not too long thereafter.

For several periodic comets, especially those with a high dust content, a different fate may be in order. While much of the dust that is ejected from a comet's nucleus never returns to it, instead continuing to travel around the sun in the comet's orbit – and, as discussed in a future "Special Topics" presentation, producing meteor showers if that orbit passes close to Earth's – some of that dust does settle back onto the nucleus.



Images I have taken of (944) Hidalgo. Left: CCD image I took on January 13, 2005. Right: Image I took on October 14, 2018 with the 2-meter Las Cumbres Observatory Faulkes Telescope North at Haleakala, Hawaii.

As seen from the "Brownlee particles" – discussed in a previous "Special Topics" presentation – this dust is very dark, and meanwhile over time it coats more and more of the nucleus, until eventually it covers the entire nucleus. The comet at that point "shuts down" and becomes an inert object essentially indistinguishable from an asteroid.

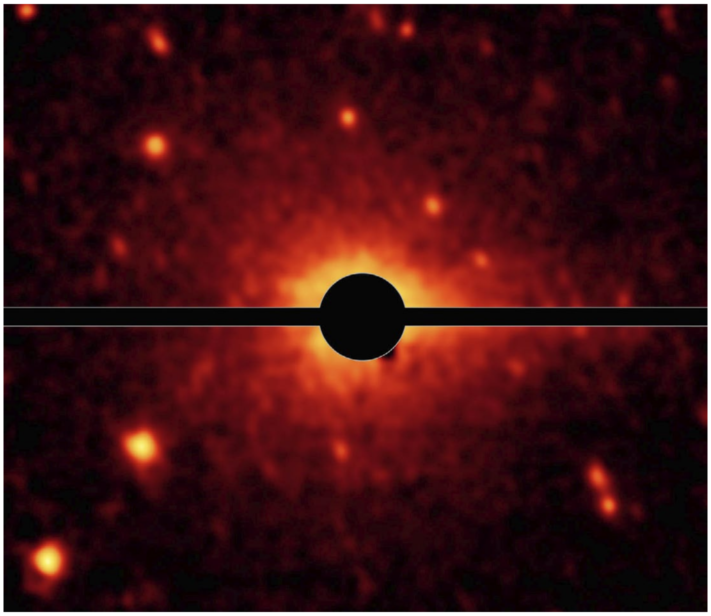
Some of the known periodic comets appear to be "transition" objects on the way from being active comets to becoming "extinct." The first such known object was Comet 28P/Neujmin 1, discovered in September 1913 by Grigorij Neujmin at the Simeis Observatory in Crimea; despite favorable viewing geometry and passing 0.55 AU from Earth it exhibited at most just a very small coma and a weak short tail no more than a few arcminutes long. It has an orbital period of 18 years and although recovered at all the subsequent returns, for most of those it has appeared entirely asteroidal, although it's fair to say that the viewing geometry tended to be unfavorable during those returns. During the one somewhat favorable return it has had since then, in 1984, it exhibited at most just a very tiny coma, which was found to be entirely gaseous in content. Studies indicated that the comet's nucleus is quite large – 21 km in diameter – but that only about 0.1% of its surface area is active.

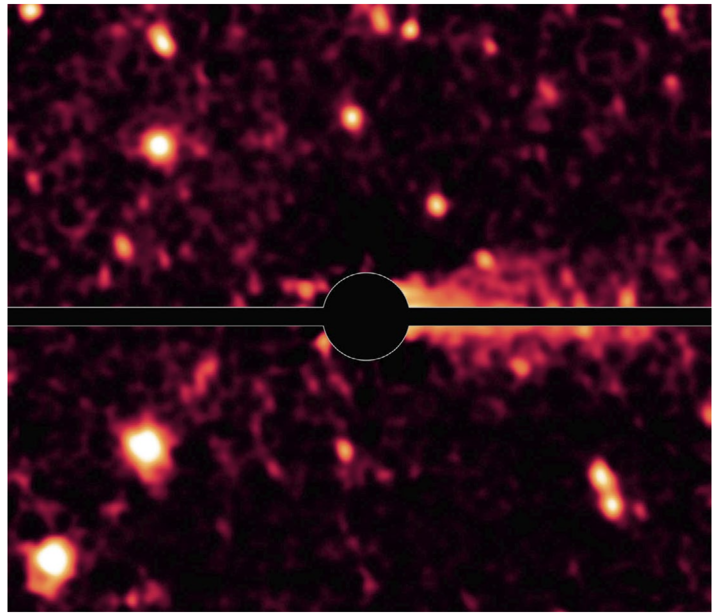
A handful of additional potential "transition" comets have been discovered during the intervening years, perhaps one of the more notable ones being 49P/Arend-Rigaux. Meanwhile, on October 31, 1920 the German-born astronomer Walter Baade, then working at Hamburg Observatory in Bergedorf, discovered a 13th-magnitude apparent asteroid now known as (944) Hidalgo. This object was found to be traveling in a distinct elliptical and inclined orbit (eccentricity 0.65, inclination 43 degrees) with a period of close to 13.6 years; its perihelion distance is close to 2 AU, but at aphelion it travels out to 9.4 AU, almost as far as Saturn. The story is told that at first Baade was unsure whether to announce his discovery as a comet or as an asteroid, finally deciding upon the latter since he felt its unusual orbit would cause his fellow astronomers to pay closer attention to it.

Hidalgo has been extensively observed and studied at every subsequent return, the most recent of which was in 2018. It has never exhibited any kind of activity that can be considered "cometary," although it is apparently very dark, as would be expected for an extinct, or dormant, cometary nucleus, and it is apparently quite large, almost 38 km in diameter.

Since Hidalgo's discovery many additional "asteroids" have been found traveling in cometary orbits, most of these discoveries having come within the past two decades as the comprehensive survey programs have become operational. Since they do not exhibit cometary activity they are not as easy to detect as are active comets, but their population must nevertheless be quite large, and in fact in a 1994 paper planetary geologist Eugene Shoemaker and his colleagues estimated that, for every active Jupiter-family periodic comet, there may be as many as 18 or more inactive, or "extinct" such comets. At least some of these objects may be in shorter-period orbits like those of the Amor- and Apollo-type asteroids, and in fact in a 2008 paper Francesca DeMeo and Richard Binzel at MIT suggested that approximately 8% of the near-Earth "asteroid" population has a cometary origin. One recent and very interesting such object is 2015 TB145, discovered by the Pan-STARRS survey program in Hawaii, which passed just 1.3 lunar distances from Earth on October 31, 2015; it travels in a highly-elongated orbit (eccentricity 0.86) with a period of three years, and is very dark as a cometary nucleus would be expected to be.

Occasionally one of these cometary "asteroids" is found to be exhibiting cometary activity at a very low level, indicating that they are not entirely "extinct" yet. A dramatic example is (3552) Don Quixote, discovered in 1983 by Paul Wild at Berne University in Switzerland; it travels in an elongated orbit (eccentricity 0.71) with an





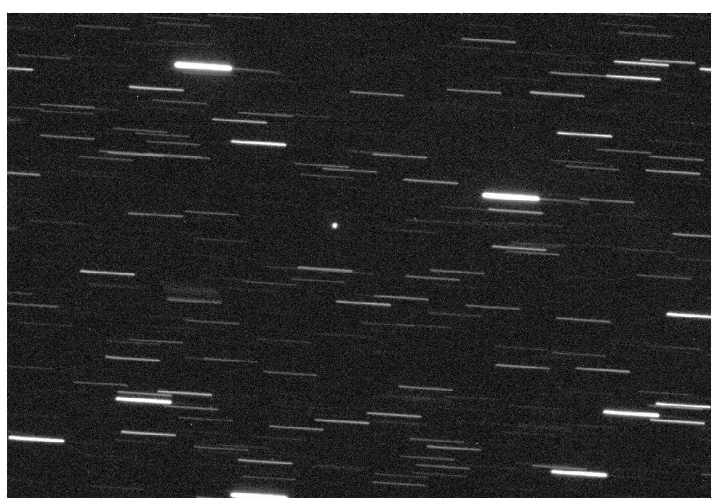
Infrared images of (3552) Don Quixote obtained with the Spitzer Space Telescope on August 22, 2009. Left: The stellar central condensation has been subtracted out, revealing the faint surrounding coma. Right: The coma has been subtracted out, revealing a faint tail. Images courtesy NASSA/JPL-CalTech/DLR/NAU.

orbital period of slightly under nine years. It had been recovered at every return since its discovery and had never exhibited cometary activity, until in 2013 when a team led by Michael Mommert (now at Northern Arizona University) announced that, in infrared data taken with the Spitzer Space Telescope during its return in 2009, Don Quixote exhibited a distinct coma and a faint tail roughly two arcminutes long. The Spitzer data is entirely consistent with sublimation of carbon dioxide and/or carbon monoxide, indicating that Don Quixote is indeed still exhibiting weak cometary activity. Meanwhile, during Don Quixote's most recent return in 2018 Mommert's team detected a faint coma and a tail at optical wavelengths.

From an astronomical point of view, Halley-type comets, and even long-period comets, can also be considered as "periodic" comets, and thus a similar fate may await some of these objects as well. In February 1991 Rob McNaught at Siding Spring Observatory in New South Wales discovered the apparent asteroid now known as (5335) Damocles, which is traveling in a highly eccentric inclined orbit (eccentricity 0.87, inclination 62 degrees) with an orbital period of 41 years; despite intense scrutiny it was never seen to exhibit cometary activity. Then, in August 1996 the NEAT survey program in Hawaii discovered the apparent asteroid 1996 PW, which was found to be traveling in an almost parabolic orbit (eccentricity 0.99) with an approximate orbital period of 5600 years. It, too, never exhibited any cometary activity.

With the advent of the comprehensive surveys, many more such objects, in both Halley-type and long-period orbits, have been discovered; some of these even travel in retrograde orbits. Collectively, these objects are now referred to as "Damocloids." Studies indicate that a small percentage of objects in the Oort Cloud may be asteroids in a physical sense and thus some of the Damocloids may indeed physically be asteroids, but it is likely that the large majority of them are extinct comets.

Despite all the ways that a comet can "die" and the large numbers of comets that have undoubtedly vanished over the lifetime of the solar system, the fact that even now, 4.6 billion years after the solar system formed, there still are as many comets as there are suggests that we will continue to see comets in our skies for as long as there are humans here to observe them. I have certainly found them to be fascinating objects to watch and study, and I hope that at least a few "Ice and Stone 2020" participants will do so as well.



An example of a Damocloid. An image I took of A/2018 V3, a long-period object discovered by Pan-STARRS with an approximate orbital period of 1340 years, on August 20, 2019 with the Las Cumbres Observatory facility at the South African Astronomical Observatory.

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