ICE & STONE 2020

WEEK 44: OCTOBER 25-31

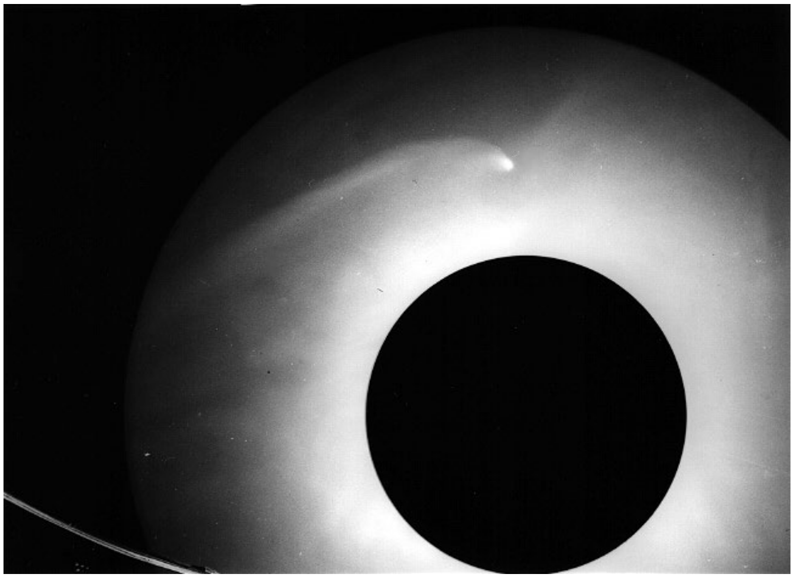
Presented by The Earthrise Institute

Authored by Alan Hale

COMET OF THE WEEK: IKEYA-SEKI 1965F

Perihelion: 1965 October 21.18, q = 0.008 AU

What would prove to be the 20th Century's brightest comet was discovered on the morning of September 18, 1965 – in a sky recently swept clean by a typhoon – by two Japanese amateur astronomers, Kaoru Ikeya and Tsutomu Seki (both of whom were veteran comet discoverers), independently and within about 15 minutes of each other. The comet was an 8th-magnitude object at the time, and traveling eastward at approximately one degree per day; within a couple of weeks it had brightened to 6th magnitude and had developed a short tail a couple of degrees long. By about this time orbital calculations were beginning to show that it was a Kreutz sungrazer, and furthermore would be appearing under just about the best viewing geometry possible for such an object, and thus hopes were high that it would put on a spectacular display.



Daytime photograph of Comet Ikeya-Seki when near perihelion on October 21, 1965, taken with a coronagraph at the Mount Norikura Solar Station of the Tokyo Astronomical Observatory. The sun is hidden behind the black occulting disk. Courtesy Tokyo Astronomical Observatory.

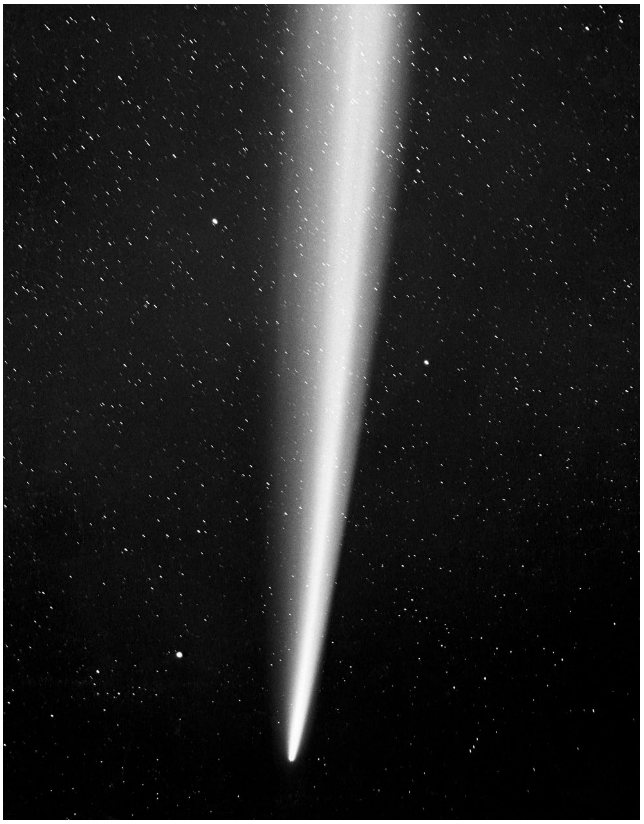
Comet Ikeya-Seki brightened rapidly during October, being close to 4th magnitude around the 7th and as bright as 2nd magnitude, with a 10-degree-long tail, by mid-month. Observations became difficult thereafter as it slipped into morning twilight, but by the 18th observers in the southern hemisphere were reporting it to be as bright as magnitude 0 deep in the dawn sky, and it began to be visible telescopically during the day.

Comet Ikeya-Seki in daytime, October 20, 1965. Courtesy Life magazine.

By October 20 the comet had brightened dramatically, and throughout the U.S. it was widely viewed as a naked-eye object during full daylight. Merely covering up the sun with an outstretched hand would allow the comet and up to two degrees of tail to be visible, and numerous brightness estimates at the time indicated that it was as bright as magnitude -10 or -11. It may have been even brighter when it passed through perihelion a few hours later; this took place after sunset from the U.S., but from Japan it was easily visible in the noontime sky just a few arcminutes from the sun itself.

The comet was again a naked-eye daylight object on October 21, although it faded noticeably as the day progressed. Telescopically it was a daytime object for another day or two, but meanwhile it was beginning to reappear back in the morning sky, and on the morning of the 25th it was reported as being as bright as magnitude -2 with a bright tail 20 degrees long. As it climbed higher each successive morning it faded, but at the same time the tail grew longer and more impressive, and at the end of the month it was reported as being about 30 degrees long or longer, bright, slender, and slightly curved.

By early November the comet had faded to 3rd or 4th magnitude, although it continued to exhibit its bright, long tail, which even late in the month was still being




Comet Ikeya-Seki in the morning sky, after perihelion. Left: From Kitt Peak National Observatory in Arizona, October 29, 1965. Courtesy Roger Lynds/NOAO/ AURA/NSF. Right: Close-up of the coma and inner tail, taken by Alan McClure from north of Los Angeles on November 1, 1965. Photo copyright Alan McClure.

reported as being 15 degrees long as seen with the unaided eye. It dropped below naked-eye visibility by early December, and thereafter faded rapidly and grew vague and diffuse; it was only about 10th magnitude in early January 1966, and was little more than a hazy patch of light when the last photographs of it were taken shortly before mid-February.

Comet Ikeya-Seki ended up being the most scientifically studied comet up until the time of its appearance. Indeed, plans to obtain observations of it had been scheduled for NASA's Gemini 6 mission which had been originally scheduled for launch on October 25, however a failure of the planed Atlas-Agena rendezvous vehicle – the primary reason for the mission – caused the mission to be delayed for several weeks. Spectroscopic observations revealed the presence of numerous metallic atoms within the comet's dust, and one interesting experiment carried out at Sacramento Peak Solar Observatory in New Mexico attempted to see if the sun's corona was affected by the comet's passage through it; no effects were detected. The comet's appearance also brought the first attempts to obtain ultraviolet observations by means of sounding rocket launches, from Wallops Island in Virginia and White Sands Missile Range in New Mexico; only the White Sands flight was successful, although it didn't produce much in the way of significant scientific results.

Japanese observers reported a pair of small apparent fragments of the comet's primary nucleus as it rounded perihelion, but these were apparently short-lived objects that soon evaporated. However, in early November a secondary nucleus began to be detected within the inner coma, and over time its separation from the primary nucleus increased, eventually reaching almost a full arcminute by the beginning of January. Individual orbital calculations for the two nuclei indicate that the primary nucleus has an approximate orbital period of 880 years, while that of the secondary nucleus is in the neighborhood of 1110 years.

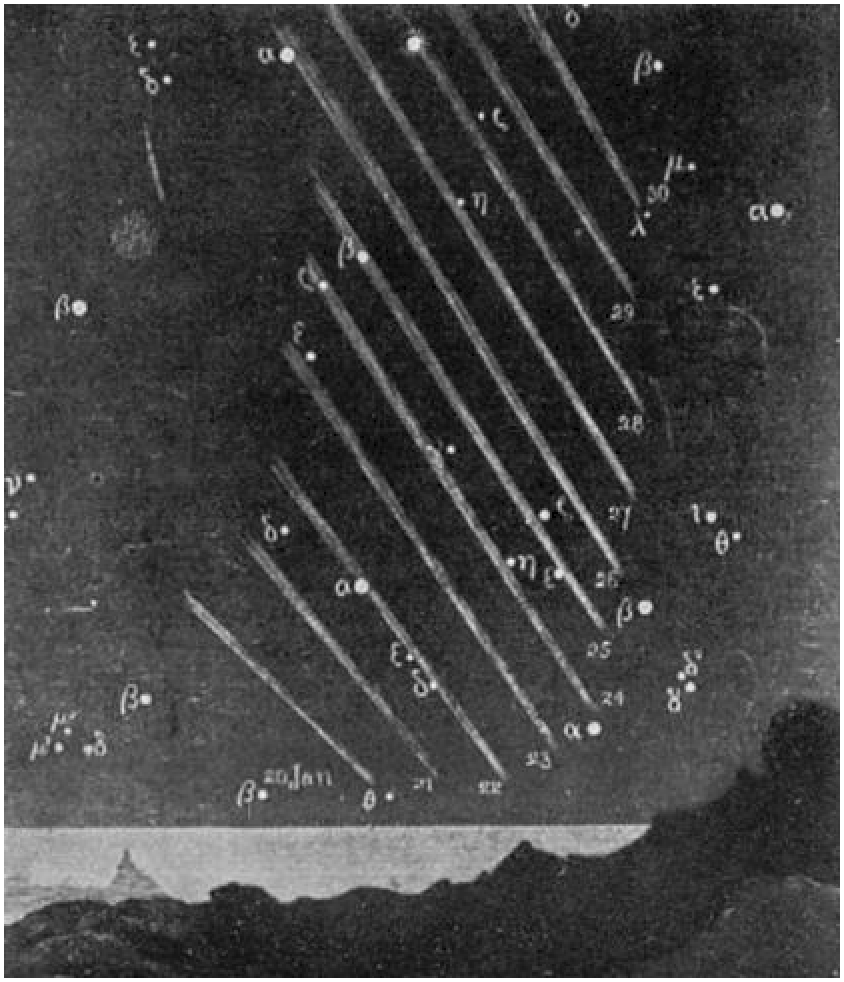
Comet Ikeya-Seki was the second – and brightest – of three Kreutz sungrazers that appeared during a seven-year period between 1963 and 1970, and as "Ice and Stone 2020" participants have undoubtedly noticed, several previous "Comets of the Week" have been Kreutz sungrazers. This most remarkable "family" of comets has produced some of the brightest comets in history and has been the subject of numerous scientific investigations, and it is the subject of this week's "Special Topics" presentation.

SPECIAL TOPIC: KREUTZ SUNGRAZERS

Observers following the Great Southern Comet of 1880, ostensibly on February 14, 1880. It was one of the Kreutz sungrazing comet that appeared around the time of the Great Comet of 1882. Courtesy State Library of Victoria.

The Great Comet of 1882 – a recent previous "Comet of the Week" – attracted a lot of attention from around the world from both astronomers and the lay public. One of the many interesting facets of this comet had been its very small perihelion distance, just a few hundred thousand km above the solar photosphere. It so happened that 2½ years earlier, i.e., in February 1880, a somewhat dimmer comet – about 3rd magnitude, although with a tail 50 to 60 degrees long – had briefly been observed from the southern hemisphere, and this comet's orbit bore a striking resemblance to that of the Great Comet of 1882. One person in particular who noticed this was the German astronomer Heinrich Kreutz, who noted that the Great Comet of 1843 – another previous "Comet of the Week" – also traveled in a very similar orbit. Since the calculated orbital periods were in the neighborhood of several centuries it was clear that these could not be returns of the same comet, and Kreutz soon speculated that they were instead returning fragments of a larger comet that had split up during a previous return. Since the Great Comet of 1882 had split into at least four separate fragments as it passed through perihelion such an occurrence would seem highly plausible.

The appearance of another comet with a similar orbit in January 1887 reinforced Kreutz's ideas in this matter. (This particular comet, which was visible only from the southern hemisphere, is unusual in that it never exhibited anything in the way of an actual "head;" instead, it appeared as a long straight tail that reached a maximum length of 35 to 40 degrees, and it is often referred to as the "headless wonder.") Kreutz also speculated that Comet Tewfik (new style designation X/1882 K1), which had appeared only during the total solar eclipse on May 17, 1882 – and which is another previous "Comet of the Week" – was another member of this comet group. In an attempt to identify a possible progenitor comet of these "sungrazing" comets, Kreutz proposed that a brilliant comet observed throughout the world in February and March 1106 (new style designation X/1106 C1) could be a potential candidate. The positional information about this comet is not good enough to permit the calculation of a reliable orbit, however the general description of its motion and appearance – including daylight visibility close to the sun in early February, when it was presumably near perihelion – is reasonably consistent with such an idea.



Motion and tail development of the "headless wonder" Comet of 1887, another Kreutz sungrazing comet that appeared around the general time of the Great Comet of 1882. From "Knowledge" by Richard Proctor.

There the matter essentially rested for the next few decades. Then, in December 1945 an astronomer at Boyden Observatory in South Africa, Daniel du Toit, discovered a 7th-magnitde comet – Comet du Toit 1945g – that appeared to be traveling in a Kreutz sungrazing orbit. Unfortunately, it was only followed for four days before disappearing into twilight, and it never reappeared after perihelion, suggesting that it had disintegrated.

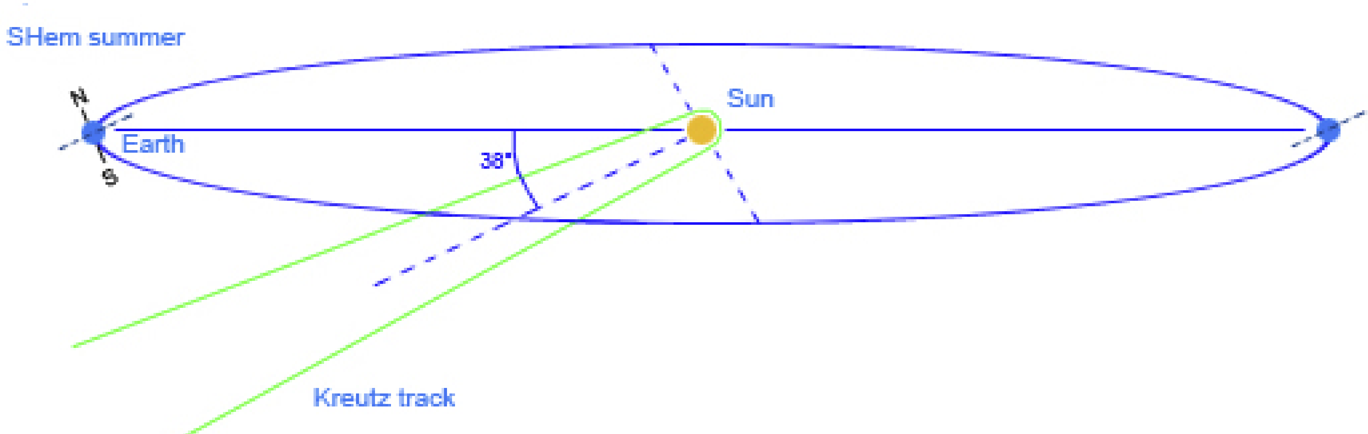
Meanwhile, there have been efforts to identify previous members of the Kreutz sungrazing group, although these efforts are hampered by the fact that the positional information in earlier centuries is often not good enough to allow for the determination of reliable orbits. The Great Comet of 1668 (new style designation C/1668 E1) looks to be a likely Kreutz sungrazer, and two bright comets that appeared later that century, the first in late 1689 (new style designation C/1689 X1) and the other in 1695 (new style designation C/1695 U1), are also reasonable candidates, although for both objects the positional information is not reliable enough for an unambiguous orbital determination. Another comet observed from the southern hemisphere for two weeks in February 1702 (new style designation X/1702 D1) was not well enough observed for any kind of orbital calculation, but its observed trajectory and overall appearance are both consistent with those of a Kreutz sungrazer.

Three Kreutz sungrazers appeared during a span of seven years beginning in the mid-1960s. The first of these was Comet Pereyra 1963e, discovered in September 1963, which initially was 5th or 6th magnitude with a pale, ghostly tail – described by some observers as a "searchlight beam" – about ten degrees long, and which faded away relatively quickly. Two years later, Comet Ikeya-Seki

Comet Pereyra 1963e, as photographed from north of Los Angeles by Alan McClure on September 21, 1963. It was one of the Kreutz sungrazing comets that appeared around the time of Comet Ikeya-Seki in 1965. Photo copyright Alan McClure.

1965f, the 20th Century's brightest comet and this week's "Comet of the Week," appeared. Finally, Comet White-Ortiz-Bolelli 1970f was as bright as 1st magnitude when it was discovered shortly after mid-May 1970, and for a while exhibited a bright tail up to 15 degrees long, but like some of the other Kreutz sungrazers it faded away rather quickly.

Around the time of these comets' appearances, the evolution of Kreutz sungrazers as a whole was thoroughly investigated by Brian Marsden, who served as Director of the IAU's Central Bureau for Astronomical Telegrams and the Minor Planet Center for several decades. Marsden noted that there were some differences in the orbital elements of the respective comets, and concluded that they came in two distinct "groups," which he named "Subgroup I" and "Subgroup II." Subgroup I included the comets of 1843 and 1880 as well as Comet Pereyra in 1963, whereas Subgroup II included the Great Comet of 1882 and Comet Ikeya-Seki in 1965 (and also probably Comet du Toit in 1945). (Comet White-Ortiz-Bolelli in 1970 is somewhat similar to the Subgroup II comets but different enough that Marsden placed it in its own category, "Subgroup IIa.") Marsden concluded that the Great Comet of 1882 and Comet Ikeya-Seki probably split from each other at a previous return, which based upon their respective orbits would have been sometime during the early 12th Century – consistent with the bright comet of 1106. The Subgroup I comets would have originated from another comet that would have appeared sometime within a few centuries of the 1106 comet, and these two perhaps split from each other during a previous return. All the Kreutz sungrazers likely originated from one single comet that appeared sometime in the



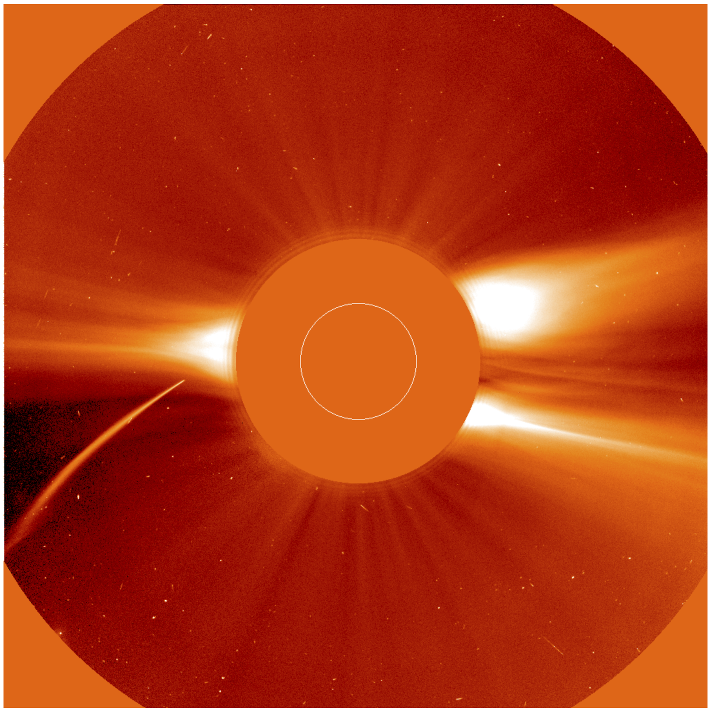
Schematic of the generic Kreutz sungrazer orbit, relative to Earth's orbit. Courtesy Rob Kaufman.

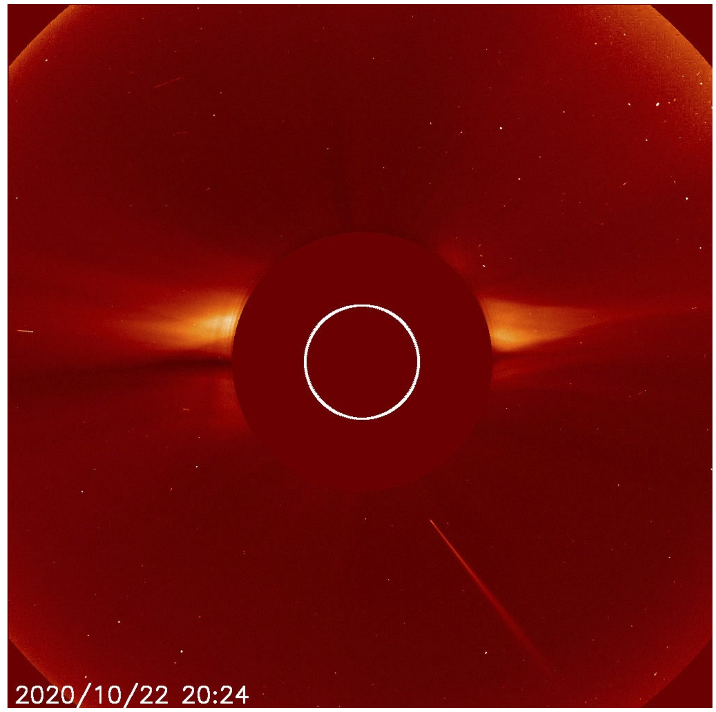
Another Kreutz sungrazing comet that appeared around the time of Comet Ikeya-Seki in 1965. Comet White-Ortiz-Bolelli 1970f (and Venus) on May 23, 1970, from the European Southern Observatory in Chile. Courtesy Hans Michael Maitzen, Anthony Moffat, and Hans-Emil Schuster.

distant past, which split into fragments, with each of these fragments subsequently undergoing their own fragmenting events during subsequent returns.

The discovery of Comet SOLWIND 1 – yet another previous "Comet of the Week" – by the U.S. Defense Department satellite P78-1 in 1979 added a fresh new wrinkle to this phenomenon once it was shown to be a Kreutz sungrazer. The subsequent discovery of several additional Kreutz sungrazers by P78-1 over the next few years, and then ten additional such objects by NASA's Solar Maximum Mission (SMM) satellite during the mid- to late 1980s, demonstrated that there was an entire population of these comets the existence of which we were quite unaware. (Upon examining their respective orbits, Marsden determined that these were all members of Subgroup I.) With the launch of the joint NASA/ESA SOlar and Heliospheric Observatory (SOHO) spacecraft in late 1995 the discovery of even smaller Kreutz sungrazing comets almost exploded, with almost 3500 having now been detected, as well as over 110 more that have been found by the later twin spacecraft of NASA's Solar and TErrestrial RElations Observatory (STEREO) mission.

While some of the SOHO Kreutz sungrazers are relatively bright in the coronagraph images, such as the "twin" Comets C/1998 K10 and C/1998 K11 that collectively constitute a previous "Comet of the Week," most of them are quite dim, some being no brighter than 8th or 9th magnitude despite their proximity to the sun. They accordingly must be very tiny objects, the nuclei of even the largest probably being no larger than a few meters in diameter. Marsden pointed out that even when some of these objects arrived just a few hours apart they sometimes were in different Subgroups, thus indicating that the formation of these comets is almost a continuous process. At a small enough level, these comets might almost constitute a "Kreutz meteor stream" raining down onto the sun.





Kreutz sungrazers in the LASCO C2 coronagraph aboard the SOlar and Heliospheric Observatory (SOHO) spacecraft. Left: The first bright SOHO sungrazer, C/1996 Y1, on December 23, 1996. Right: An as-yet-undesignated Kreutz sungrazer that appeared last week; image taken October 22, 2020. Both images courtesy NASA/ESA.

Zdenek Sekanina and Paul Chodas at NASA's Jet Propulsion Laboratory undertook a detailed re-examination of the Kreutz sungrazers' orbital evolution during the mid-2000s, utilizing both historical data as well as data on the spacecraft-discovered Kreutz comets up until that time. While the Great Comet of 1882 and Comet Ikeya-Seki had both undergone distinct fragmentation events at their respective perihelion passages – and presumably other Kreutz sungrazers have done so as well – Sekanina and Chodas argue that additional fragmenting may have occurred much farther away from the sun, even around aphelion. (There is distinct circumstantial evidence that this has happened with other comets.) In this context, the Subgroups are not as important as might appear to be at face value, and in fact comets formed from the same fragmenting event may actually migrate from one Subgroup to another.

Sekanina and Chodas point out that the bright Kreutz sungrazers have often arrived in "clusters" where several of them appear over a short period of time. Once such "cluster" seems to have occurred during the late 17th Century, and one definitely occurred during the 1880s with another one in the 1960s. In this scenario the various comets within a given cluster all result from the same fragmenting event that would have taken place at a large heliocentric distance, and the appearances of comets from different Subgroups within any given "cluster" is thus not a coincidence.

In terms of the overall evolutionary picture, Sekanina and Chodas suggest that, while the Great Comet of 1882 and Comet Ikeya-Seki did have a common progenitor comet, that object may not have been the comet of 1106 but instead another comet that appeared within the same general timeframe but for whatever reason – perhaps because it came at a time of the year when Kreutz sungrazers are under poor viewing geometry – was not recorded. That comet, and the 1106 comet, were in turn the returning fragments of a comet that had split previously; possible candidates for this object are comets that appeared in February 423 and February 467. As for the original progenitor comet, there has often been speculation that this might have been a brilliant comet that appeared in 372 B.C., however all the information about this comet seems to be second-hand, and thus it is difficult at best to establish any kind of meaningful connection. Sekanina and Chodas propose that a comet observed from China in 214 B.C. may possibly be the Kreutz progenitor comet.

Meanwhile, in a 2007 paper Sekanina and Chodas made the prediction that, based upon their overall analysis, another "cluster" of bright Kreutz sungrazing comets was on its way into the inner solar system and, in their words, "is expected to arrive in the coming decades, its earliest member possibly just several years from now." Less than 4½ years later, what may very well have been this "earliest member" appeared, Comet Lovejoy C/2011 W3. This is a future "Comet of the Week," and I will continue the story of the Kreutz sungrazers in that Presentation.

THIS WEEK IN HISTORY

OCTOBER **25** 26 27 28 29 30 31

OCTOBER 25, 2020: Comet ATLAS C/2020 M3, discovered this past June 27 by the ATLAS survey in Hawaii, will pass through perihelion at a heliocentric distance of 1.268 AU. Comet ATLAS, which is a Halley-type object with an approximate orbital period of 139 years, has been unexpectedly bright (8th magnitude) lately, and may become even brighter as it passes 0.36 AU from Earth in mid-November. Information about Comet ATLAS is available at the Comet Resource Center.

25 OCTOBER **26** 27 28 29 30 31

OCTOBER 26, 1366: Comet 55P/Tempel-Tuttle, the parent comet of the Leonid meteor shower, passes only 0.023 AU from Earth, the second-closest confirmed cometary approach to Earth in history. The closest cometary approaches to Earth are listed and discussed in a previous "Special Topics" presentation, and the relationship between comets and meteor showers is discussed in a future "Special Topics" presentation.

OCTOBER 26, 1914: Comet Delavan 1913f passes through perihelion at a heliocentric distance of 1.104 AU. Intrinsically, it was one of the brightest comets to appear during the 20th Century, and it is a previous "Comet of the Week."

OCTOBER 26, 2006: NASA's twin Solar TErrestrial RElations Observatory (STEREO) spacecraft are launched from Cape Canaveral, Florida. Both spacecraft carry instruments, including coronagraphs, with which several comets have been discovered near the sun. Many of these comets are Kreutz sungrazers, which are the subject of this week's "Special Topics" presentation.

NASA'S dual STEREO spacecraft, whose mission is the first to take measurements of the sun and solar wind in 3-D, are seen undergoing final preparation within the clean room at Astrotech, a processing facility near Kennedy Space Center during May 2006. Courtesy NASA/Jim Grossmann.

OCTOBER 26, 2018: A team of Hungarian astronomers led by Gabor Horvath of Eotvos Lorand University in Budapest announces that they have confirmed the existence of the Kordylewski clouds, large clouds of dust near the Earth-moon L4 and L5 Lagrangian points first reported in 1961. The Kordylewski clouds are discussed in a previous "Special Topics" presentation.

OCTOBER 26, 2028: The Apollo-type asteroid (35396) 1997 XF11 will pass 0.0062 AU from Earth. The initial calculations of this encounter, first computed in 1998, indicated a much closer approach, which was subsequently corrected when more data became available. The story of this prediction, and the underlying process, are discussed in a previous "Special Topics" presentation.

25 26 OCTOBER 27 28 29 30 31

OCTOBER 27, 1577: The Great Comet of 1577, often referred to as "Tycho Brahe's Comet," passes through perihelion at a heliocentric distance of 0.178 AU. This comet played a crucial role in our overall understanding of comets, and it is a future "Comet of the Week."

OCTOBER 27, 1699: Comet 55P/Tempel-Tuttle, the parent comet of the Leonid meteor shower, passes 0.065 AU from Earth.

OCTOBER 27, 1948: The Eclipse Comet of 1948 passes through perihelion at a heliocentric distance of 0.135 AU. This comet, and other "eclipse comets," are discussed in a previous "Special Topics" presentation.

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OCTOBER 28, 1937: Karl Reinmuth at Heidelberg Observatory in Germany discovers the asteroid now known as (69230) Hermes. Two days later Hermes passed two lunar distances from Earth, the closest-known asteroidal approach to Earth for over fifty years. Hermes itself was lost until re-discovered in 2003. Hermes' story will be discussed in detail in a future "Special Topics" presentation.

25 26 27 28 OCTOBER 29 30 31

OCTOBER 29, 1991: NASA's Galileo mission, while traversing the asteroid belt en route to its eventual encounter with Jupiter, flies by the main-belt asteroid (951) Gaspra, the first encounter of an asteroid by a spacecraft. Galileo's asteroid encounters are discussed in a previous "Special Topics" presentation.

OCTOBER 29, 2005: A team led by Steven Ostro discovers a moon of the near-Earth asteroid (1862) Apollo – the first-known Apollo-type asteroid – in radar data taken with the large radio telescope in Arecibo, Puerto Rico. Asteroids' moons are the subject of a previous "Special Topics" presentation.

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OCTOBER 30, 1937: Two days after its discovery, the Apollo-type asteroid now known as (69230) Hermes passes 0.0050 AU – 1.9 lunar distances – from Earth. This remained the record closest-known asteroidal approach to Earth until 1989.

OCTOBER 30, 1974: At a scientific conference on comets, Donald Brownlee of the University of Washington announces the results of studies of lightweight particles collected from the upper atmosphere by high-flying aircraft. These "Brownlee particles" are apparently grains of cometary dust, and are discussed in a previous "Special Topics" presentation.

25 26 27 28 29 30 OCTOBER 31

OCTOBER 31, 1920: Walter Baade at Bergedorf Observatory in Germany discovers the apparent asteroid now known as (944) Hidalgo, which was found to be traveling in a cometary orbit – the first-known asteroid to do so. Hidalgo is quite likely an extinct cometary nucleus, and these objects are discussed in next week's "Special Topics" presentation.

OCTOBER 31, 2015: The Apollo-type asteroid 2015 TB145, which had been discovered by the Pan-STARRS survey program in Hawaii three weeks earlier, passes 0.0032 AU – 1.3 lunar distances – from Earth. 2015 TB145 travels in a somewhat cometary orbit and also exhibits physical characteristics that suggest it may be an extinct cometary nucleus; these objects are discussed in next week's "Special Topics" presentation.

OCTOBER 31, 2021: The James Webb Space Telescope is scheduled to be launched from Kourou, French Guiana. Webb, which will be placed near the Earth-Sun L2 Lagrangian point 1.5 million km directly anti-sunward of Earth, is sometimes touted as being the successor to the Hubble Space Telescope, although its detector sensitivity is primarily in the infrared.

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