ICE & STONE 2020

WEEK 20: MAY 10-16, 2020

Presented by The Earthrise Institute

#20

Authored by Alan Hale

THIS WEEK IN HISTORY

MAY
10 11 12 13 14 15 16

MAY 10, 1999: The LINEAR survey in New Mexico discovers the near-Earth asteroid now known as (162173) Ryugu. Ryugu was the destination of JAXA's Hayabusa2 sample-return mission, which arrived there in mid-2018 and departed there late last year, and which is now en route back to Earth with its collected samples. The Hayabusa2 mission is discussed in future "Special Topics" presentations.

MAY
10 11 12 13 14 15 16

MAY 11, 1983: Comet IRAS-Araki-Alcock 1983d passes 0.031 AU from Earth, the closest confirmed cometary approach to Earth during the 20th Century. It is this week's "Comet of the Week," and cometary flybys of Earth are the topic of this week's "Special Topics" presentation.

MAY 11, 2020: The main-belt asteroid (363) Padua will occult the 5.5-magnitude star Psi Cancri. The predicted path of the occultation crosses parts of the southwestern U.S. and northern Mexico. This event is described in more detail in last week's "Special Topics" presentation.

MAY
10 11 12 13 14 15 16

MAY 12, 2006: The primary component of Comet 73P/Schwassmann-Wachmann 3 passes 0.079 AU from Earth. This comet began splitting apart in the mid-1990s, and in 2006 over 60 different fragments were detected as they passed by Earth. This and other close cometary flybys of Earth are discussed in this week's "Special Topics" presentation.

MAY 12, 2013: The Canada-France-Hawaii 3.6-meter telescope at Mauna Kea Observatory in Hawaii records images of Comet PANSTARRS C/2017 K2, four years before that object's discovery. The comet was active despite being at a heliocentric distance of 23.74 AU. It does not pass through perihelion (heliocentric distance 1.8 AU) until 2½ years from now and could become quite bright; it is a future "Comet of the Week."

MAY 12, 2020: The main-belt asteroid (3151) Talbot will occult the 6th-magnitude triple-star system HD 144362 in Ophiuchus. The predicted path of the occultation crosses northeastern South America, a few locations in Central America, the Yucatan Peninsula in Mexico, and parts of the southern and western U.S. This event is discussed in more detail in last week's "Special Topics" presentation.

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. Courtesy of NASA/JPL-Caltech.

10 11 12 **MAY 13** 14 15 16

MAY 13, 1861: Australian amateur astronomer John Tebbutt discovers a 4th-magnitude comet. At the end of June Comet Tebbutt passed just 0.13 AU from Earth and became one of the brightest and most spectacular comets of the 19th Century. It is a future "Comet of the Week."

10 11 12 13 **MAY 14** 15 15

MAY 14, 1864: A meteorite, comprising up to 20 separate fragments, falls near the town of Orgueil in southern France. The Orgueil meteorite is a carbonaceous chondrite and is one of the most-intensely studied meteorites of this type. Carbonaceous chondrites are the subject of a future "Special Topics" presentation.

10 11 12 13 14 **MAY 15** 16

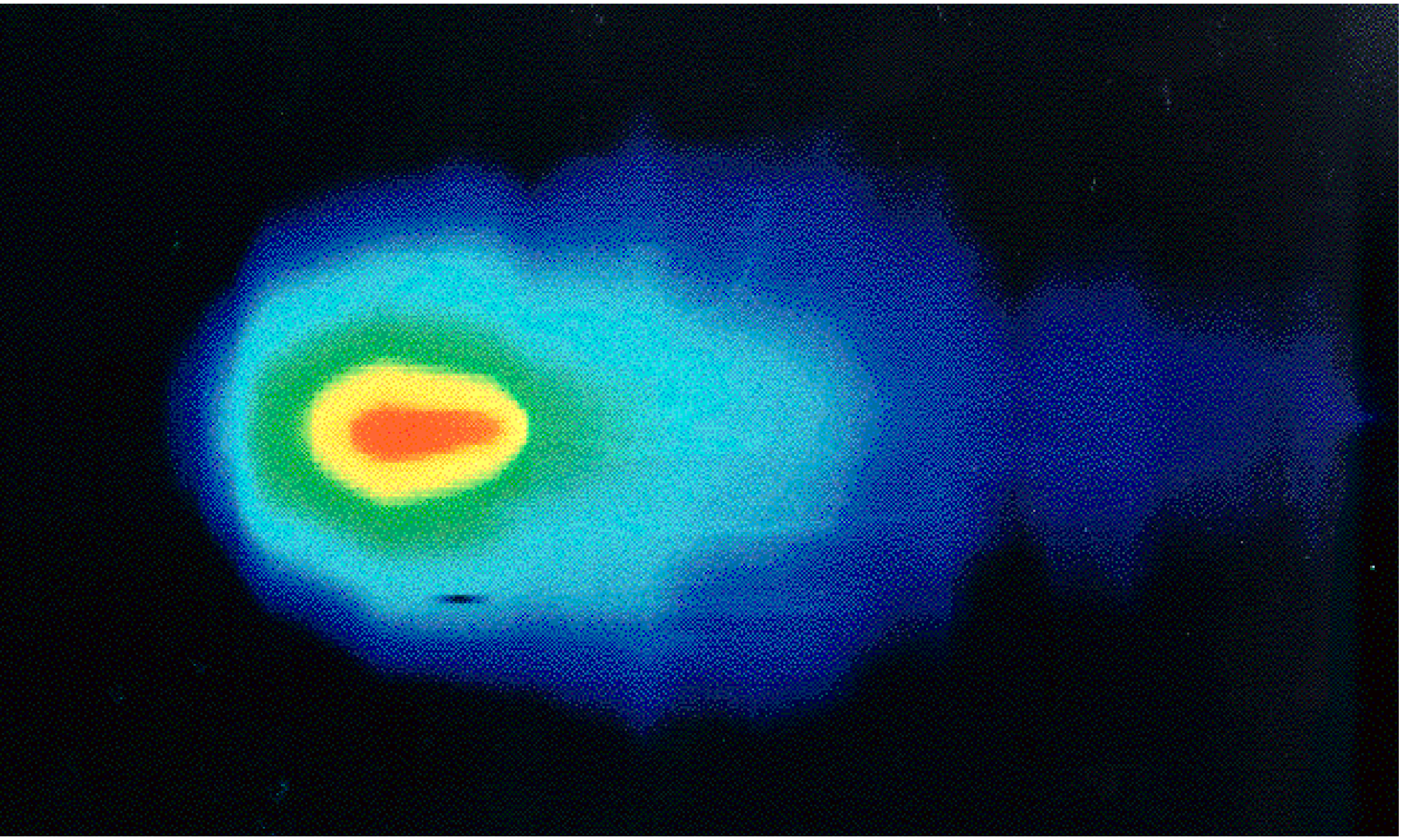
MAY 15, 2005: Astronomers using the Hubble Space Telescope discover Pluto's moons Nix and Hydra, the second and third known moons of that world. Pluto and its moons are the subject of a future "Special Topics" presentation.

10 11 12 13 14 15 **MAY 16**

MAY 16, 1918: Japanese astronomer Kiyotsugu Hirayama submits a paper describing his recognition of "families" of asteroids in the main asteroid belt, i.e., asteroids sharing similar orbits and a likely common origin. The subject of asteroid "families" is discussed in a future "Special Topics" presentation.

COMET OF THE WEEK: IRAS-ARAKI-ALCOCK 1983D

Perihelion: 1983 May 21.25, q = 0.991 AU



Infrared image of Comet IRAS-Araki-Alcock obtained by the IRAS spacecraft. Courtesy NASA/IPAC.

On January 25, 1983, the InfraRed Astronomical Satellite (IRAS) spacecraft was launched from Vandenberg Air Force Base in California. For the next ten months, until its supply of superfluid liquid helium coolant ran out, IRAS surveyed the entire sky in near- to far-infrared wavelengths, and its findings completely revolutionized much of our knowledge about the solar system, the Galaxy, and the entire universe.

On April 25 – three months after its launch – the infrared sensors aboard IRAS detected a "fast-moving object." Due to some breakdowns in communication and some initial uncertainty as to just what this object was, it wasn't until early May that astronomers finally determined that the new IRAS object was a previously-unknown comet. By that time the comet had been independently discovered on May 3 by two amateur astronomers: Genichi Araki in Japan and George Alcock in England. (Alcock was a very well-known amateur astronomer who had discovered four comets from the late 1950s through mid-1960s as well as several novae after that, and at the time of his discovery of this comet was searching for novae with binoculars from indoors through a closed window!) Visual observations at the time indicated that the comet was as bright as 6th magnitude and exhibited a large coma 15 to 20 arcminutes in diameter.

Orbital calculations soon indicated that Comet IRAS-Araki-Alcock was rapidly approaching Earth, and would pass just 0.031 AU from Earth on May 11 – the closest confirmed cometary approach to Earth in over two centuries. It brightened rapidly as it approached Earth, and a couple of days before its closest approach it was as bright as 3rd magnitude with a coma approximately one degree in diameter; it never exhibited much in the way of a tail.

On the night of closest approach, May 10-11, the comet was as bright as 2nd magnitude with a coma

Comet IRAS-Araki-Alcock on May 11, 1983, during the time of its closest approach to Earth. Photograph courtesy Alan Gorski.

between 2 and 3 degrees across. At the beginning of the night in was located a few degrees west of the "bowl" of the Big Dipper, and was moving towards the southwest at two degrees per hour. To the unaided eye it appeared as a diffuse cloud, but telescopically it exhibited a number of fanlike features, streamers, and pillar-like structures throughout the inner coma. The sight of the comet's central condensation traveling against the background stars in "real time" remains among the most dramatic sights I have seen in all my years of comet observing.

During its passage by Earth the Arecibo radio telescope in Puerto Rico and the Deep Space Network's tracking antenna in Goldstone, California both successfully detected the comet's nucleus via radar – the first radar detections of a long-period comet -- with the data indicating that the nucleus is a non-spherical object some five to eight km in diameter, and accompanied by a dense swarm of "particles" (centimeter-sized and larger) out to a distance of approximately 800 km or more. The International Ultraviolet Explorer (IUE) satellite detected the presence of diatomic sulfur (S2) in the inner coma; since this molecule can only be formed and maintained in very cold conditions, this tells us much about the environments within which comets are formed.

Following its passage by Earth Comet IRAS-Araki-Alcock rapidly headed southward and within a couple of days was accessible only from the southern hemisphere. After maintaining its brightness for another day or so it faded rapidly, dropping below naked-eye visibility during the third week of May and to 7th magnitude by the end of the month. It was followed visually until mid-July, and the final observations were obtained in early October.

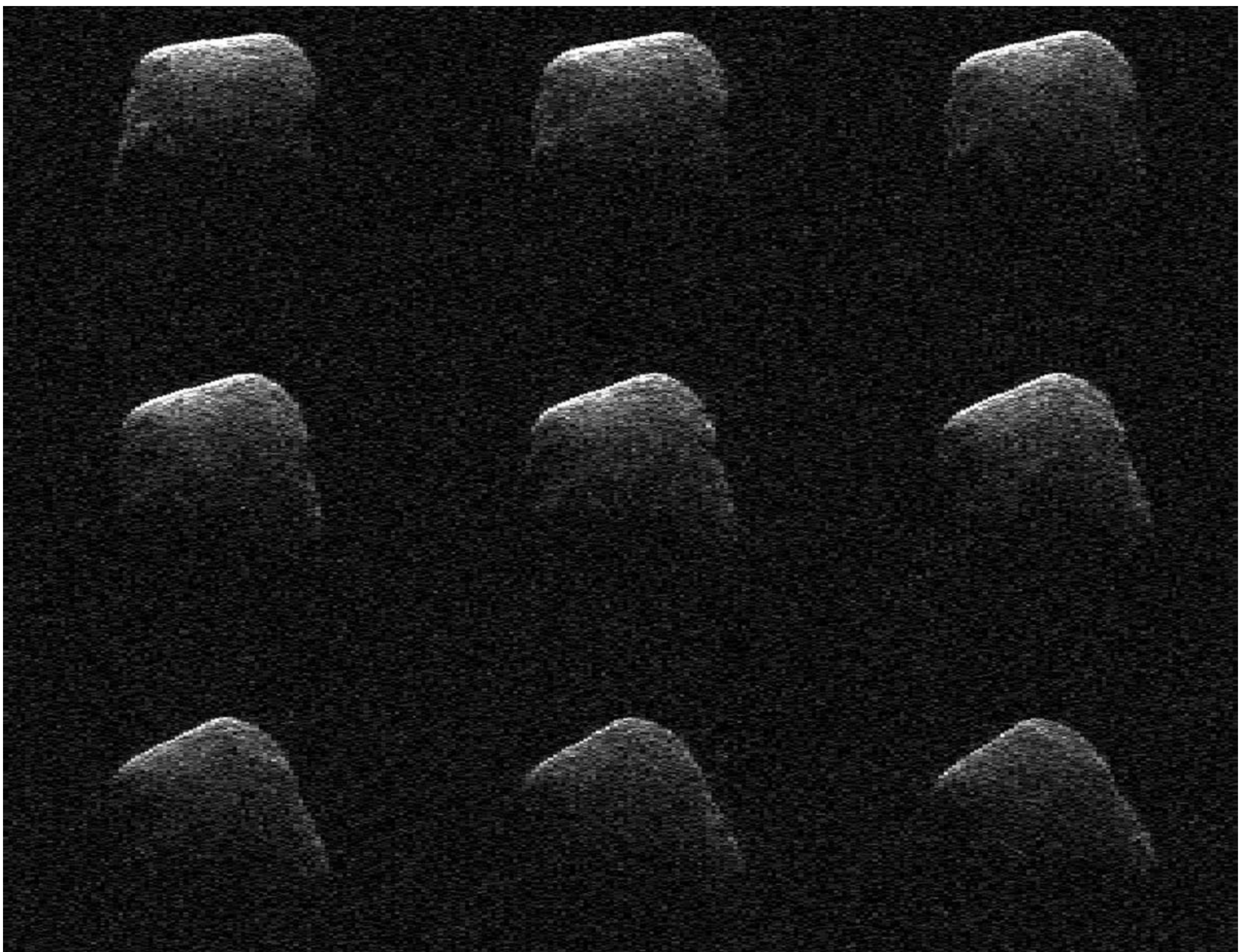
Comet IRAS-Araki-Alcock's approach to Earth was the closest confirmed cometary approach during the entire 20th Century, and at this writing is the fifth-closest confirmed approach in all of recorded history. Close cometary approaches to Earth, both past and future, are discussed in this week's "Special Topics" presentation.

By a most remarkable coincidence, the comet that accounted for the 20th Century's fourth-closest confirmed approach to Earth was discovered while all the excitement was taking place with Comet IRAS-Araki-Alcock. Comet Sugano-Saigusa-Fujikawa 1983e was independently discovered by three Japanese amateur astronomers on May 8, having already passed through perihelion on May 1 at a heliocentric distance of 0.471 AU. This newer comet was apparently much smaller than its predecessor, with radar bounce observations indicating that its nucleus was no more than a few hundred meters in diameter, and while it did reach 6th magnitude at the time of its closest approach of 0.063 AU on June 12 it appeared as little more than a vague diffuse cloud one degree in diameter. It faded rapidly after that and disappeared from view within a week.

SPECIAL TOPIC: CLOSE COMETARY ENCOUNTERS

The "Comet of the Week" this week is Comet IRAS-Araki-Alcock 1983d, which passed just 0.031 AU (4.68 million km, or 12.2 lunar distances) from Earth on May 11, 1983 – the closest confirmed cometary approach to Earth during the 20th Century, and the fifth-closest confirmed such approach in all of recorded history. Within this context, it is perhaps appropriate to examine some of the other very close approaches of comets to Earth.

The comet that has made the closest confirmed approach to Earth was discovered on June 14, 1770 by the renowned French comet-hunter Charles Messier. At that time it was located in Sagittarius and perhaps close to 5th or 6th magnitude, but it brightened rapidly over the subsequent couple of weeks as it approached Earth. On July 1 it passed just 0.0151 AU (2.26 million km, or 5.9 lunar distances) from Earth, and according to Messier and other observers of that time was as bright as 1st or 2nd magnitude and exhibited a coma up to 2½ degrees in diameter (although apparently without any appreciable tail). Within about three days after its closest approach it disappeared into sunlight; Messier later recovered it in the morning sky on August 3 and followed it for the next two months before it faded from view.



Radar images of the nucleus of Comet PANSTARRS P/2016 BA14 obtained on March 22, 2016 (during its close approach to Earth) by NASA's DSN tracking antenna at Goldstone, California. Courtesy NASA/JPL.

According to orbital calculations performed by Swedish mathematician Anders Lexell – for whom the comet was eventually named – the comet was a short-period object with a period of only 5.6 years, and had been placed into that orbit as a result of a very close approach to Jupiter (0.02 AU) in 1767. After being missed due to poor viewing geometry in 1776, Comet Lexell passed even closer to Jupiter (0.0015 AU) in 1779, with the results of that encounter being very difficult to predict; it is possible that the comet was placed into a much-longer period orbit (a few centuries) or perhaps even ejected from the solar system altogether. A re-examination of Comet Lexell's orbit in 2018 by Chinese-American astronomer Quan-Zhi Ye and his colleagues suggests that the Apollo-type asteroid (529668) 2010 JL33 might possibly be a remnant of Comet Lexell, although it is not possible to establish a definite linkage. (This object passed just 0.043 AU from Earth in late 2010 and became as bright as 13th magnitude, but does not come close again until a moderately close approach of 0.12 AU in December 2045.)

The 20 closest cometary approaches to Earth in recorded history are listed in the following table:

Rank	Comet	Approach date	Distance (AU)
1.	Lexell 1770 I	1770 July 1	0.015
2.	55P/Tempel-Tuttle	1366 October 26	0.023
3.	PANSTARRS P/2016 BA14	2016 March 22	0.024
4.	289P/Blanpain P/2003 WY25	2003 December 11	0.025
5.	IRAS-Araki-Alcock 1983d	1983 May 11	0.031
6.	1P/Halley	837 April 10	0.033
7.	252P/LINEAR	2016 March 21	0.036
8.	3D/Biela 1806 I	1805 December 9	0.037
9.	Grischow 1743 I	1743 February 8	0.039
10.	7P/Pons-Winnecke 1927c	1927 June 26	0.039
11.	Comet of 1014 (C/1014 C1)	1014 February 24	0.041
12.	Comet of 1702 (C/1702 H1)	1702 April 20	0.044
13.	Comet of 1132 (C/1132 T1)	1132 October 7	0.045
14.	Comet of 1351 (C/1351 W1)	1351 November 29	0.048
15.	Comet of 1345 (C/1345 O1)	1345 July 31	0.048
16.	209P/LINEAR	2014 May 29	0.055
17.	Comet of 1499 (C/1499 Q1)	1499 August 17	0.059
18.	45P/Honda-Mrkos-Pajdusakova	2011 August	0.060
19.	73P/Schwassmann-Wachmann 3 1930d	1930 May 31	0.062
20.	Sugano-Saigusa-Fujikawa 1983e	1983 June 12	0.063

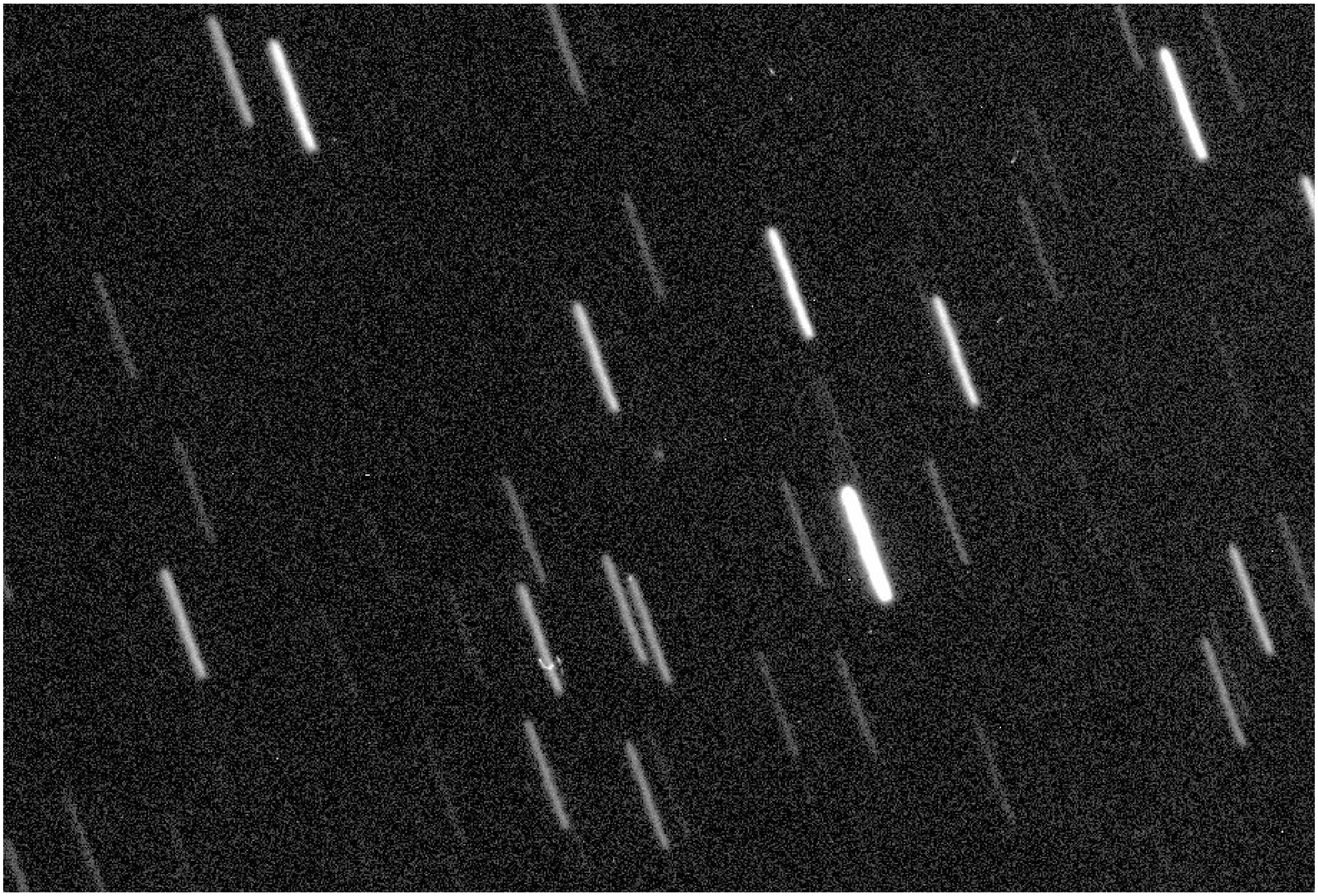
Comet 1P/Halley is discussed in a previous "Special Topics" presentation, and Comet 55P/Tempel-Tuttle, the parent comet of the Leonid meteor shower, is discussed in a future "Special Topics" presentation. Comet 3D/Biela, which no longer exists, is a previous "Comet of the Week." Comet Grischow in 1743 is possibly a short-period comet, but it has never been seen since. The comet of 1702 is not the same object as a bright comet seen earlier that year (X/1702 D1) that may have been a Kreutz sungrazer. The comet of 1499 is possibly identical to Comet Levy 1991q, which was found to be a Halley-type comet with an orbital period of 51 years, and when that object returns in 2042 it should be possible to confirm (or disprove) that identity.

In similar fashion, the following table lists the 20 closest cometary approaches during the “Ice and Stone 2020” era, i.e., within the past 50 years – coincident with the period of time that I have been actively observing comets.

Rank	Comet	Approach date	Distance (AU)
1.	PANSTARRS P/2016 BA14	2016 March 22	0.024
2.	289P/Blanpain P/2003 WY25	2003 December 11	0.025
3.	IRAS-Araki-Alcock 1983d	1983 May 11	0.031
4.	252P/LINEAR	2016 March 21	0.036
5.	209P/LINEAR	2014 May 29	0.055
6.	45P/Honda-Mrkos-Pajdusakova	2011 August 15	0.060
7.	Sugano-Saigusa-Fujikawa 1983e	1983 June 12	0.063
8.	46P/Wirtanen	2018 December 16	0.077
9.	73P/Schwassmann-Wachmann 3	2006 May 12	0.079
10.	45P/Honda-Mrkos-Pajdusakova	2017 February 11	0.083
11.	107P/Wilson-Harrington P/1979 VA	1979 October 30	0.091
12.	289P/Blanpain	2020 January 11	0.091
13.	252P/LINEAR P/2000 G1	2000 March 4	0.097
14.	Hyakutake C/1996 B2	1996 March 25	0.102
15.	300P/Catalina P/2005 JQ5	2005 June 27	0.103
16.	Suzuki-Saigusa-Mori 1975k	1975 October 31	0.104
17.	103P/Hartley 2	2010 October 20	0.121
18.	Catalina P/2009 WX51	2009 December 25	0.147
19.	169P/NEAT	2005 August 7	0.147
20.	6P/d’Arrest 1976e	1976 August 12	0.151

The lone “Great Comet” on this list is Comet Hyakutake C/1996 B2, which is a previous “Comet of the Week.” Comet 103P/Hartley 2 was encountered by the EPOXI mission (rescaled from the Deep Impact spacecraft) around the time of its 2010 approach to Earth, and an image from this encounter is featured in a previous “Special Topics” presentation.

Photographs I have taken of two recent close-approaching comets. Left: Comet 252P/LINEAR on April 3, 2016. Right: Comet 46P/Wirtanen on December 14, 2018.

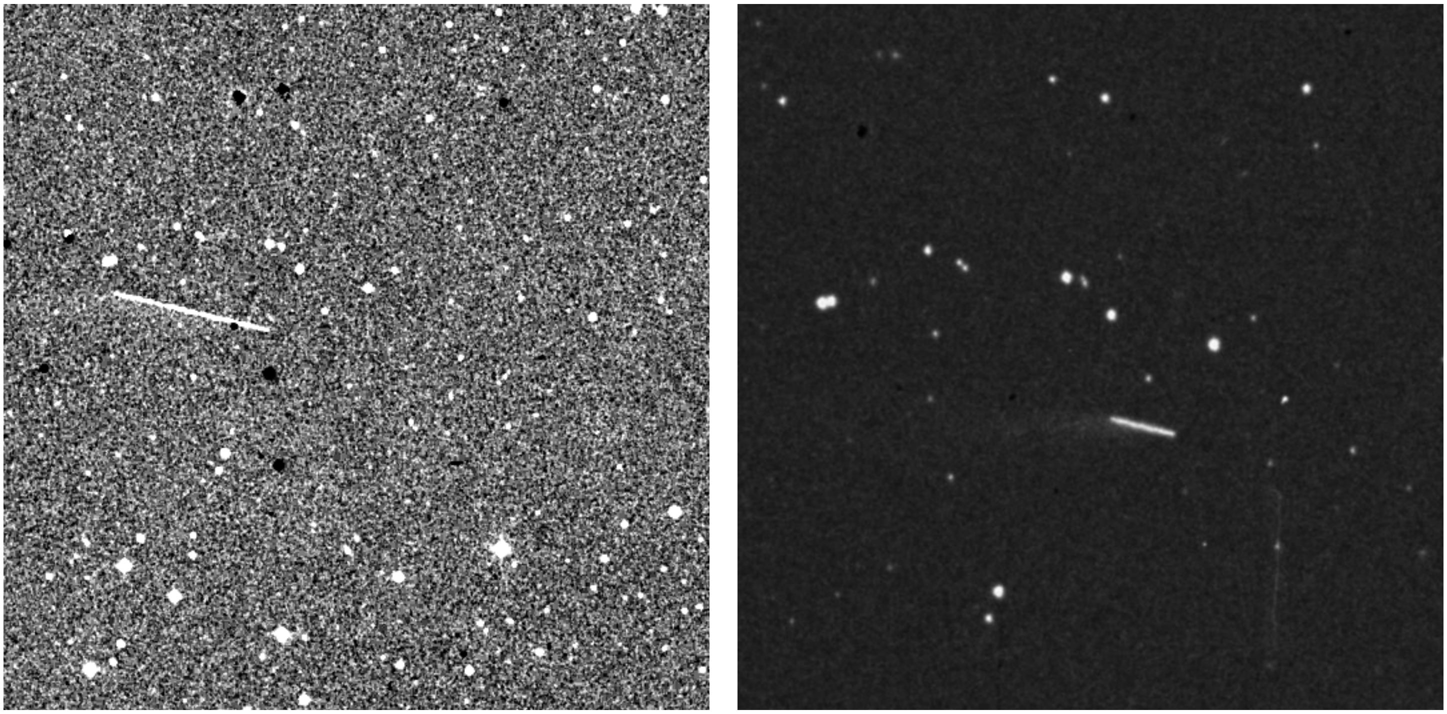


Comet 289P/Blanpain on January 4, 2020, as imaged by the Las Cumbres Observatory facility at Teide Observatory in the Canary Islands. Despite being only 0.101 AU from Earth at the time, the comet appears as a barely non-stellar object of 18th magnitude.

The top entry on this list and the Number 3 entry on the "recorded history" list, Comet PANSTARRS P/2016 BA14, was a very dim object which appeared almost stellar and never was brighter than 13th magnitude despite its close distance, however radar studies with the DSN tracking antenna at Goldstone, California suggested that its nucleus is close to 1 km in diameter, indicating that it is only very weakly active. Its orbit bears a striking similarity to that of Comet 252P/LINEAR, which passed close to Earth at the same time, and which despite having a smaller nucleus was much brighter (close to 4th or 5th magnitude). This comet was much brighter intrinsically in 2016 than during its discovery return in 2000, when it also came close to Earth (although it wasn't discovered until over a month later); it makes another close approach in 2032 (see below).

Comet 73P/Schwassmann-Wachmann 3, which had passed close to Earth during its discovery return in 1930 (Number 19 on the "recorded history" list) had split up in the mid-1990s, with over 60 fragments being detected during the close approach in 2006; some of these were bright enough to be visually detectable, and passed even closer to Earth than the primary fragment (which the distance in the above table refers to). An infrared image of the comet, with several of these fragments, taken by the Spitzer Space Telescope is included in a previous "Special Topics" presentation.

Comet 289P/Blainpain was discovered as far back as 1819 and was an obvious comet then, but had been lost ever since. At its re-discovery in 2003 it initially appeared asteroidal and was never brighter than 15th magnitude, however in March 2004 a faint coma was detected with large telescopes. It experienced an apparent outburst in 2013 over a full year before its perihelion passage but was not seen again on that



The trailed discovery images of Comet 107P/Wilson-Harrington, taken November 19, 1949 with the 1.2-meter Schmidt telescope at Palomar Observatory in California. Left: red exposure (45 minutes), enhanced to bring out the faint tail. Right: blue exposure (12 minutes); the tail is evident. Courtesy Palomar Observatory/National Geographic/Digitized Sky Survey/ European Southern Observatory.

return. On its most recent return it was duly recovered last year, but despite its close approach to Earth this past January it remained a tiny and faint object, never brighter than about 17th magnitude.

Comet 107P/Wilson-Harrington was discovered in November 1949 during the course of the National Geographic-Palomar Observatory Sky Survey being conducted with the recently-built 1.2-meter Schmidt telescope; it exhibited an obvious tail (although no apparent coma) on both the red and blue discovery plates, but not on plates taken on subsequent nights. It was only followed for four nights and then subsequently lost. It was re-discovered by Eleanor Helin from Palomar in November 1979 but appeared completely asteroidal, and in fact was considered to be an "ordinary" Apollo-type asteroid and later assigned the number (4015); the identity with the lost Comet Wilson-Harrington was not established until 1992. It has never exhibited cometary activity outside of its discovery images, and its true physical nature remains unclear. It will pass close to Earth again in 2039 (see below).

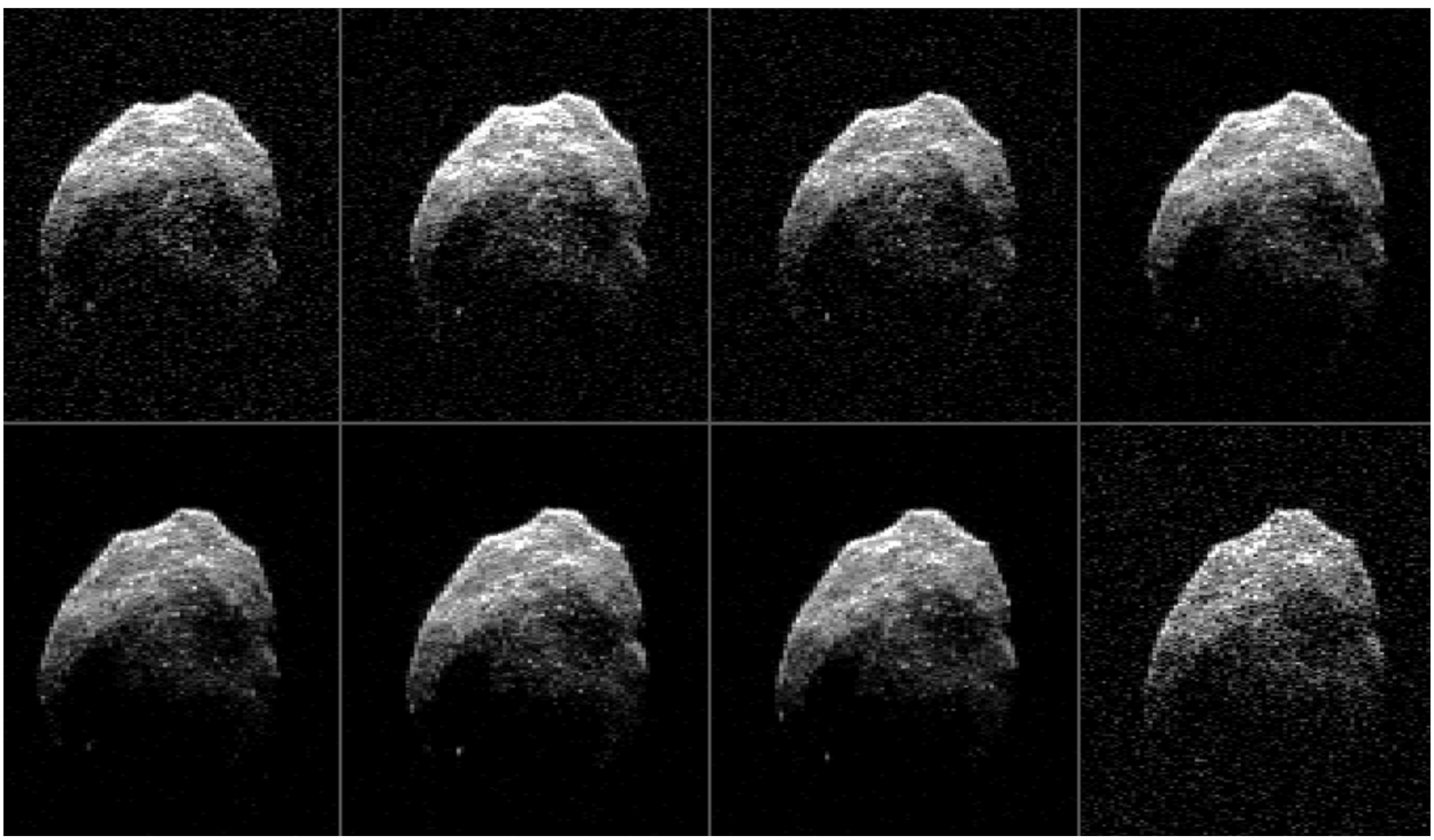
There are some objects that I am excluding from the above lists. The LASCO coronagraphs aboard the SOlar and Heliospheric Observatory (SOHO) spacecraft have detected numerous comets – with some of these perhaps better being described as "apparent comets" – some of which have been found to be traveling on short-period orbits. One of these is P/1999 J6, which is a member of a group the existence of which was first pointed out by Brian Marsden, and which has an orbital period close to 5.5 years and which has been seen (in LASCO images) on two returns since then. Orbital calculations indicate it would have passed just 0.013 AU from Earth on June 12, 1999, one month after perihelion passage (when it appeared in the LASCO images); nothing had been recorded in any of the survey programs operating at the time, although it's fair to point out that its existence wasn't detected until a year later. Another of these "comets," now designated as 323P/SOHO, would have passed 0.058 AU from Earth on January 13, 2000, again one month after it was discovered in LASCO images. Although these are called "comets," their appearance is basically stellar in the LASCO images, and they have never been detected from the ground; their exact physical nature is unclear.

During the late 19th and early 20th Centuries there were several reports of various fast-moving diffuse objects that, in theory at least, could have been small comets passing very close to Earth. The validity of these reports is difficult to evaluate, and the fact that there haven't been any such reports over the past several decades

An example of the aurora-like STEVE phenomenon. This photograph was taken on August 17, 2015 by Elfie Hall at Little Bow Resort, Alberta. It is conceivable that the "possible comet" reported in May 1916 by Estelle Glancy and Charles Perrine at Cordoba Observatory in Argentina was an occurrence of STEVE. Courtesy Elfie Hall, licensed by Creative Commons.

(when modern equipment and observing techniques are being utilized) is worrisome, but on the other hand some of the reports were made by experienced and capable observers of the time, and the intrinsic brightnesses of these supposed "comets" are reasonably consistent with the dimmer comets that are being discovered nowadays. Julius Franz, then-Director of the observatory at Breslau University (now the University of Wroclaw in Poland) reported seeing such an object in July 1911, and Estelle Glancy and Charles Perrine of the Cordoba Observatory in Argentina reported another such object in May 1916. (Perrine, then-Director of the Cordoba Observatory, had previously worked at Lick Observatory in California, where he discovered nine comets as well as Jupiter's sixth and seventh moons.) It is perhaps conceivable that the Glancy-Perrine object was an example of the aurora-like phenomenon now called STEVE (Strong Thermal Emission Velocity Enhancement) that has only become recognized within recent years. In any event, in the absence of any confirming information I am excluding these objects from the above lists.

Also excluded from these lists are the objects usually described as "active asteroids" (which are the subject of a future "Special Topics" presentation). Although in some contexts these can perhaps be considered as "comets" – and, indeed, one of them is a previous "Comet of the Week" – the activity they have been seen to exhibit is, in general, due to mechanisms other than sublimation of volatile substances. (3200) Phaethon, which is generally considered as being the parent "comet" of the Geminid meteor shower, and which in fact has exhibited weak cometary activity around some of its perihelion passages, passed 0.121 AU from Earth on December 10, 2007 and 0.069 AU from Earth on December 16, 2017. NASA's OSIRIS-REx mission, presently in orbit around the near-Earth "asteroid" (101955) Bennu, detected several bursts of jetting activity from that object in early 2019 when it was near perihelion; Bennu passed 0.015 AU from Earth on September 22, 1999 (a week and a half after its discovery) and 0.033 AU from Earth on September 20, 2005.



Radar images (transmitted by the DSN tracking antenna in California, received by the National Radio Astronomy Observatory's 100-meter radio telescope in West Virginia) of the potential extinct comet 2015 TB145 during that object's extremely close flyby of Earth on October 31, 2015. The object is approximately 600 meters in diameter. Courtesy NASA/JPL/NRAO

Finally, these lists do not include apparent "asteroids" that might be "extinct" or possibly "dormant" comets. (These objects are discussed in a future "Special Topics" presentation.) Several such objects have passed close to Earth from time to time; the closest such approach was by 2015 TB145, which passed only 0.00325 AU (486,000 km, or 1.27 lunar distances) from Earth on October 31, 2015. (This object was popularly called names like the "Skull Asteroid" since radar images showed two surface indentations remarkably similar to the appearance of eye sockets on a human skull, and since its approach to Earth took place on Halloween.) The Damocloid 1999 XS35 (orbital period 75 years) had passed 0.045 AU from Earth on November 5, 1999, four weeks before its discovery.

Comets will, of course, continue to approach Earth from time to time in the future; I have pointed out in a previous "Special Topics" presentation that Comet 1P/Halley will pass just 0.096 AU from Earth during its 2134 return, and meanwhile Comet 109P/Swift-Tuttle – the parent comet of the Perseid meteor shower, and a future "Comet of the Week" – will make moderately close approaches to Earth during both of its next two returns (in 2126 and 2261). In the near term, while for obvious reasons any forthcoming close approaches by as-yet-undiscovered comets cannot be predicted, we can certainly determine when already-known short-period comets will be coming close by. The following table lists those short-period comets that will be passing within 0.2 AU of Earth during the next two decades.

Comet	Approach date	Distance (AU)
364P/PANSTARRS	2023 April 7	0.121
169P/NEAT	2026 August 11	0.167
249P/LINEAR	2029 November 3	0.057
252P/LINEAR	2032 March 15	0.058
15P/Finlay	2034 August 13	0.185
289P/Blanpain	2035 November 6	0.082
300P/Catalina	2036 June 9	0.051
141P/Machholz 2	2036 December 19	0.125
Catalina P/2009 WX51	2037 April 18	0.052
107P/Wilson-Harrington	2039 October 31	0.108

"Active asteroids" and potential "extinct" comets that will be making close approaches to Earth during this same interval include: (14827) Hypnos, 0.078 AU on June 2, 2024; (2101) Adonis, 0.036 AU on February 7, 2036; (101955) Bennu, 0.099 AU on February 11, 2037; 2015 HX176, 0.099 AU on April 1, 2038; (16960) 1998 QS52, 0.081 AU on June 10, 2039; and (2201) Oljato, 0.100 AU on December 16, 2040.

Earth certainly isn't the only planet that comets pass close to; the other planets get their occasional cometary visitors as well. Jupiter has comets passing by all the time – often significantly affecting their orbits in the process – and, of course, we have already seen one comet strike Jupiter (Comet Shoemaker-Levy 9, in 1994; this is a future "Comet of the Week"). Just two examples of many comet/planet encounters that have taken place in recent years include an approach to Mars of 0.072 AU by Comet ISON C/2012 S1 – a future "Comet of the Week" – on October 1, 2013, and an approach to Mercury of only 0.025 AU by Comet 2P/Encke – another future "Comet of the Week" – on November 18 of that same year. The ultimate "near-miss" encounter took place in October 2014 and involved Mars and Comet Siding Spring C/2013 A1; this event will be described in that comet's "Comet of the Week" presentation.

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