ICE & STONE 2020

Week 8: February 16-22, 2020

Presented by The Earthrise Institute

THIS WEEK IN HISTORY

16 | FEBRUARY 17 | 18 | 19 | 20 | 21 | 22

FEBRUARY 17, 1930: A bright meteor appears in the sky above the midwestern U.S. and falls to the ground near Paragould, Arkansas. With a total mass of 370 kg, the Paragould meteorite, a stony chondrite, is the second-largest meteorite fall seen from and recovered in North America.

FEBRUARY 17, 1996: The Near-Earth Asteroid Rendezvous (NEAR) spacecraft – later renamed NEAR Shoemaker after renowned planetary geologist Eugene Shoemaker – is launched from Cape Canaveral, Florida. After passing by the main-belt asteroid (253) Mathilde in June 1997 and the near-Earth asteroid (433) Eros in late 1998, NEAR Shoemaker returned to Eros in February 2000 and went into orbit around it, and one year later successfully soft-landed onto Eros' surface. The NEAR Shoemaker mission was covered in a previous "Special Topics" presentation.

16 | 17 | FEBRUARY 18 | 19 | 20 | 21 | 22

FEBRUARY 18, 1930: Clyde Tombaugh at Lowell Observatory in Arizona discovers Pluto while examining photographs he had taken in late January. Pluto is the subject of a future "Special Topics" presentation.

FEBRUARY 18, 1948: A bright meteor appears over the midwestern U.S. and drops a large shower of meteorites over parts of Kansas and Nebraska. The Norton County meteorite, as this has been called, has a total mass of 1070 kg and is the largest meteorite fall seen from and recovered in North America.

FEBRUARY 18, 1991: Rob McNaught at Siding Spring Observatory in New South Wales discovers the apparent "asteroid" now known as (5335) Damocles. Damocles is traveling in an elongated Halley-type orbit (eccentricity 0.87, orbital period 41 years) and may be an extinct cometary nucleus. It is the first-known of the objects now called "Damocloids," which are discussed in a future "Special Topics" presentation.

***THERE ARE NO CALENDAR ENTRIES FOR FEBRUARY 16 AND 20.**

COVER IMAGES CREDITS:

Front cover (top): Image of C/2014 Q2 (Lovejoy), a long-period comet discovered on 17 August 2014 by Terry Lovejoy. This photograph was taken from Tucson, Arizona, using a Sky-Watcher 100mm APO telescope and SBIG STL-11000M camera. Courtesy John Vermette.

Front cover (bottom): Artist's impression of NASA's Dawn spacecraft arrival at the giant asteroid Vesta on July 15, 2011. Courtesy NASA/JPL-Caltech.

Back cover: Composite image taken by JAXA's Hayabusa-2 spacecraft just before touchdown on the Ryugu asteroid to collect a sample in 2019. Courtesy JAXA, Chiba Institute of Technology, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Meiji University, University of Aizu, AIST).

FEBRUARY 19, 1958: The large main-belt asteroid (3) Juno occults the 9th-magnitude star HD 32203 in Orion. This was the first predicted such event at which observations were attempted; a positive report was made from Sweden but seems to have been a false alarm. These events are discussed in a future "Special Topics" presentation.

FEBRUARY 21, 2019: JAXA's Hayabusa2 spacecraft successfully collects soil samples from the near-Earth asteroid (162173) Ryugu, around which it was in orbit at the time. Hayabusa2 and similar missions will be the subject of a future "Special Topics" presentation.

FEBRUARY 21, 2019: Scott Sheppard, David Tholen, and Chad Trujillo announce their discovery of what appears to be the most distant observed object in the solar system. The object, nicknamed "FarFarOut," was found in images taken in January 2018 with the Subaru Telescope in Hawaii, and appears to be located at an approximate heliocentric distance of 140 AU and perhaps is somewhere around 400 km in diameter. At this time there is no information available as to its orbit. Objects like this in the distant outer solar system are discussed in a future "Special Topics" presentation.

FEBRUARY 22, 1906: Max Wolf at Heidelberg Observatory in Germany discovers the asteroid now known as (588) Achilles, the first known "Jupiter Trojan" asteroid. Trojan asteroids are the subject of a future "Special Topics" presentation.

FEBRUARY 22, 2018: The main-belt asteroid (1165) Imprinetta occults the 10th-magnitude star BD -7d 3286 in Crater. Although most such events are used to determine characteristics of the occulting asteroid, in this case successful observations with the high-time-resolution VERITAS array in Arizona were used to determine physical characteristics of the occulted star, the first time that this was successfully accomplished. Stellar occultations by asteroids are the subject of a future "Special Topics" presentation.

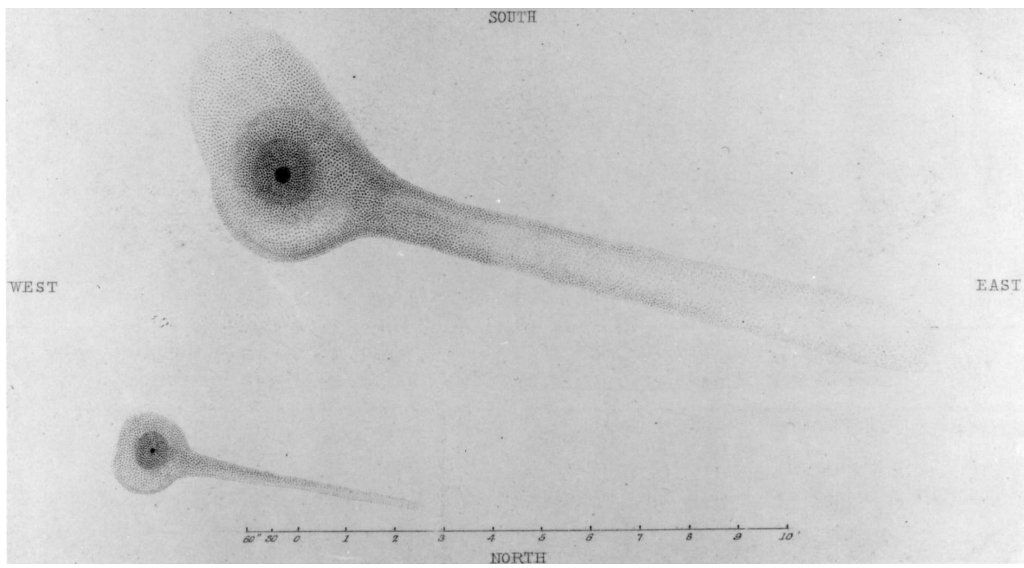
FEBRUARY 22, 2020: The main-belt asteroid (97) Klotho will occult the 7th-magnitude star HD 30913 in Orion. The predicted path of the occultation crosses central India, Nepal (including Kathmandu), Tibet, China (including Tianjin and southern Beijing), northern North Korea, and the Japanese island of Hokkaido (including Sapporo).

COMET OF THE WEEK: 3/D BIELA 1846 II

Perihelion: 1846 February 11.49, q = 0.856 AU

The stories of the first two numbered periodic comets, 1P/Halley and 2P/Encke – both of which are future "Comets of the Week" – are well known. The third numbered periodic comet also has an interesting story, but unlike the earlier two it will likely never be seen again, at least, in "cometary" form.

The comet was first discovered on March 8, 1772 by the French astronomer and comet hunter Jacques Montaigne, a contemporary and competitor of Charles Messier (who himself independently spotted it shortly thereafter). It remained just below naked-eye visibility (i.e., around 7th magnitude) and was followed for slightly under one month. Five returns later the French comet hunter Jean Louis Pons discovered it on November 10, 1805; on December 9 of that year it passed just 0.037 AU from Earth and was easily seen with the unaided eye at 4th magnitude or brighter. Some of the mathematical astronomers of that era, among them Carl Gauss, noticed a similarity between the 1806 comet and the 1772 comet but could not establish an identity between them.



The two components of Comet Biela on February 19, 1846 as sketched by Otto Wilhelm von Struve at Pulkovo Observatory near St. Petersburg, Russia.

An Austrian army officer, Wilhelm von Biela, discovered a comet on February 27, 1826; as he was also skilled at computing orbits he soon determined it was likely that this comet was the same as the comets that had appeared in 1772 and 1806. It was followed for long enough that year such that the link between them could be firmly established, and the orbital period was determined as being 6.7 years.

The comet returned as expected in 1832 but was missed at the unfavorable return in 1839. At the following return the then-Director of the Vatican Observatory, Francesco de Vico, recovered it on November 26, 1845. Initially there didn't seem to be anything unusual about it, but starting in mid-January 1846 a "companion" comet was found to be accompanying the main one. This "companion" remained visible until the end of March with the primary comet subsequently being followed for another month. The following return, in 1852, was not an especially favorable one, but once again the "companion" comet appeared alongside the primary one during most of the one-month-long interval that they were visible.

The next return, in 1859, was very unfavorable and the comet was not recovered. The viewing geometry at the return after that, in 1866, was very favorable, however, with the comet's being expected to pass 0.22 AU from Earth in late February, but despite several careful searches the astronomers of that era found… nothing. The comet likewise failed to show up at the subsequent return in 1872, however on November 27 of that year an intense meteor shower – with rates up to 10,000 meteors per hour – was seen coming from the general area of the constellation Andromeda. Similar strong "Andromedid" showers appeared in 1885 – during which the first successful photograph of a meteor was taken, by Hungarian astronomer Ladislaus Weinek – and in 1892, and a weaker shower appeared in 1899. All of these were around the time that Comet Biela would have been passing through perihelion, and although the Andromedid shower itself had been known since 1741, the shower's strong displays those years combined with the comet's splitting and then failure to appear have been construed as evidence that the comet completely disintegrated not too long after the middle of the 19th Century.

A representation of the Andromedid meteor shower over France on November 27, 1872, as presented by French science journalist Amedee Guillemin.

There have nevertheless been some attempts to recover Comet Biela in the years since then. One of the strongest efforts took place in 1971, when Brian Marsden calculated that if some asteroidal fragment remained and if it had ceased activity around 1859, it would be passing close to Earth late that year. Despite several searches, no trace of Biela was found then, nor at any other time. For what it's worth, in 2001 the NEAT survey program discovered a faint periodic comet that travels in an orbit quite similar to that of Biela, but is apparently an unrelated object; now known as Comet 207P/NEAT, it will pass 0.22 AU from Earth in March 2024.

The lack of any strong Andromedid activity after 1899 has often been taken as a sign that Comet Biela has all but completely dispersed, however meteor expert Peter Jenniskens has pointed out that the dust stream that produces the Andromedid shower has likely shifted away from Earth due to gravitational perturbations from the planets, and in fact there does appear to be some very weak Andromedid activity from time to time. On December 5, 2011, a moderately strong Andromedid shower, with a peak rate of some 50 meteors per hour, was seen from Canada. A shower with similar rates that was expected to occur in 2018 apparently did not take place, but a possible Andromedid shower with potential rates as high as 200 meteors per hour may occur in 2023. The entire art of predicting meteor showers has developed dramatically during the past couple of decades, and the linkage between comets and meteor showers is the subject of a future "Special Topics" presentation.

Meanwhile, there seems to be a modern-day equivalent, of sorts, to Comet Biela. Comet 141P/ Machholz 2 abruptly brightened to 7th magnitude and was accompanied by up to four "companion" comets (two of which were fairly bright) during its discovery return in 1994. One of these "companion" comets returned with the primary component in 1999, although it soon faded out. The comet was poorly placed for observation in 2005 and 2010, but was well placed in 2015; it was significantly fainter (12th magnitude) than it had been previously but was again accompanied by a fainter "companion" comet. It passes perihelion again late this year, under favorable viewing conditions (with its passing 0.52 AU from Earth in mid-January 2021) and . . . we'll see what happens.

SPECIAL TOPIC: STELLAR INTRUDERS

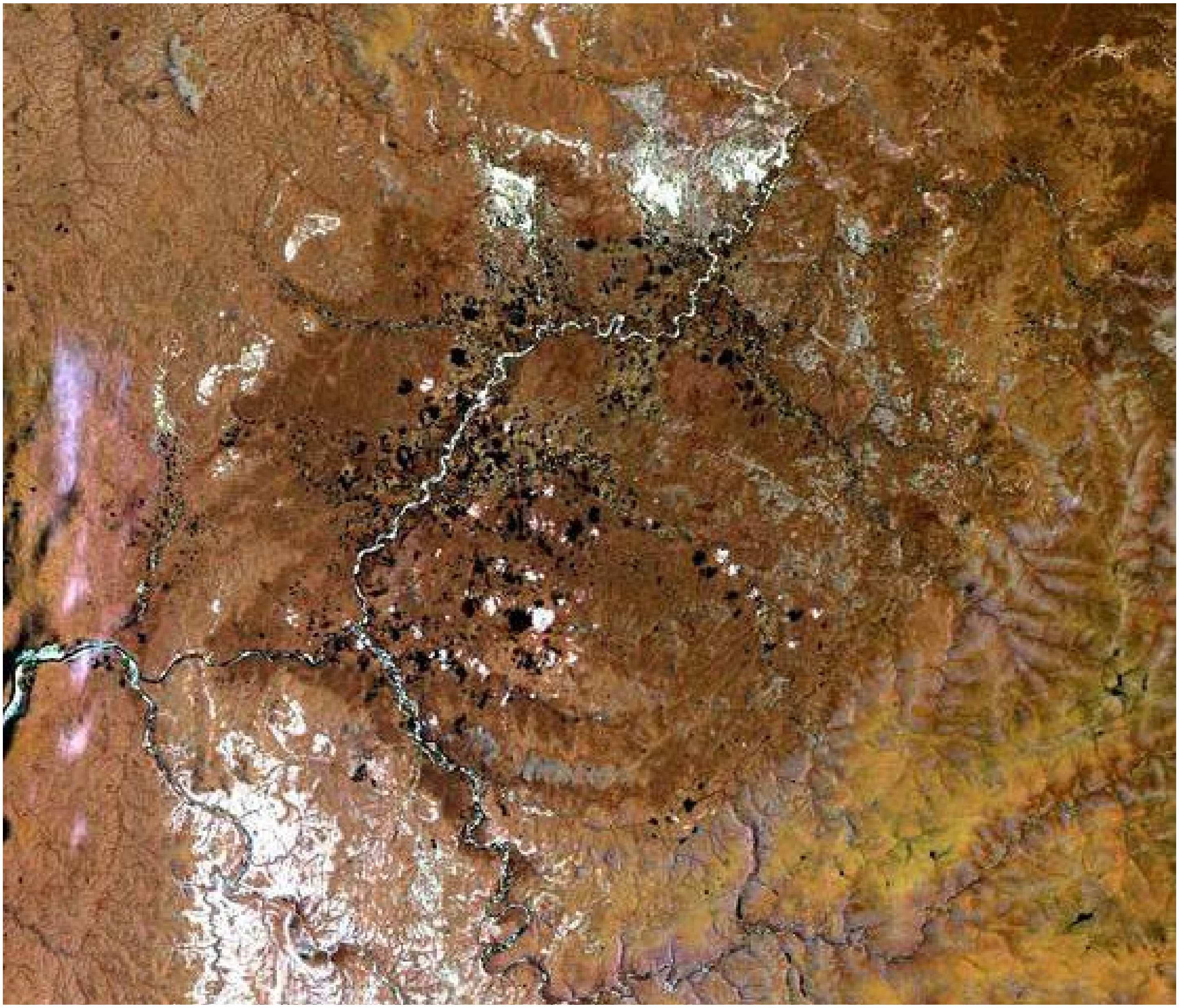
Artist's conception of a possible "comet shower" during the late Eocene Epoch. Courtesy Michael Carroll.

Five weeks ago I devoted the "Special Topics" presentation to the subject of the Oort Cloud, the large spherical cloud of comets that is believed to enshroud the solar system out to distances of several tens of thousands of Astronomical Units. The comets in the Oort Cloud have been there since the forming Jupiter and other planets ejected them out there in the earliest days of the solar system, and – in keeping with Isaac Newton's First Law of Motion – will remain there until acted upon by an outside force. The force that would do so is, of course, gravity.

The comets that are out at these distances are only loosely held by the sun's gravity. As the sun has made its travels through and around the Galaxy in the roughly 4 ½ billion years since it and the Oort Cloud comets were formed, it has certainly from time to time encountered other stars that have passed near the Oort Cloud and that have accordingly gravitationally disturbed those comets that were nearby. At the same time, the combined mass of all the stars and other matter in the galaxy creates a tidal force that acts on the Oort Cloud, that would likely be strongest on those occasions every few tens of millions of years when the sun passes through the plane of the Galaxy's equator. Many comets, perhaps a significant majority of them, that are so perturbed would be ejected into interstellar space away from the sun's gravitational influence altogether, and thus there would be a steady "drainage" away from the Oort Cloud. Some comets, meanwhile, would be perturbed inward towards the inner solar system, and these are the long-period comets that we see today.

A star passing through the Oort Cloud would gravitationally perturb a large number of comets, and a non-trivial fraction of these would be "kicked in" towards the inner solar system. It would take some time for these comets to arrive: by Kepler's Third Law, a comet in a circular orbit at a heliocentric distance of, say, 20,000 AU would take one million years to make the journey to the sun's vicinity. Since the various comets would be arriving from varying distances, their arrival times would be spread out over a period of perhaps centuries to millennia, but during that time the flux of long-period comets would be much higher – by a factor of ten, perhaps even a hundred or more – than the normal flux of these objects. Such an event could be called a "comet shower."

The nighttime skies of Earth during such a period would be quite dramatic, with perhaps several long-tailed naked-eye comets being visible at any given time. At the same time, however, such a dramatic increase in the flux of long-period comets would substantially increase the probability of one or more of them impacting Earth during the duration of such a "shower." Since these comets have "fallen in" from the outer solar system – many of them, perhaps, on

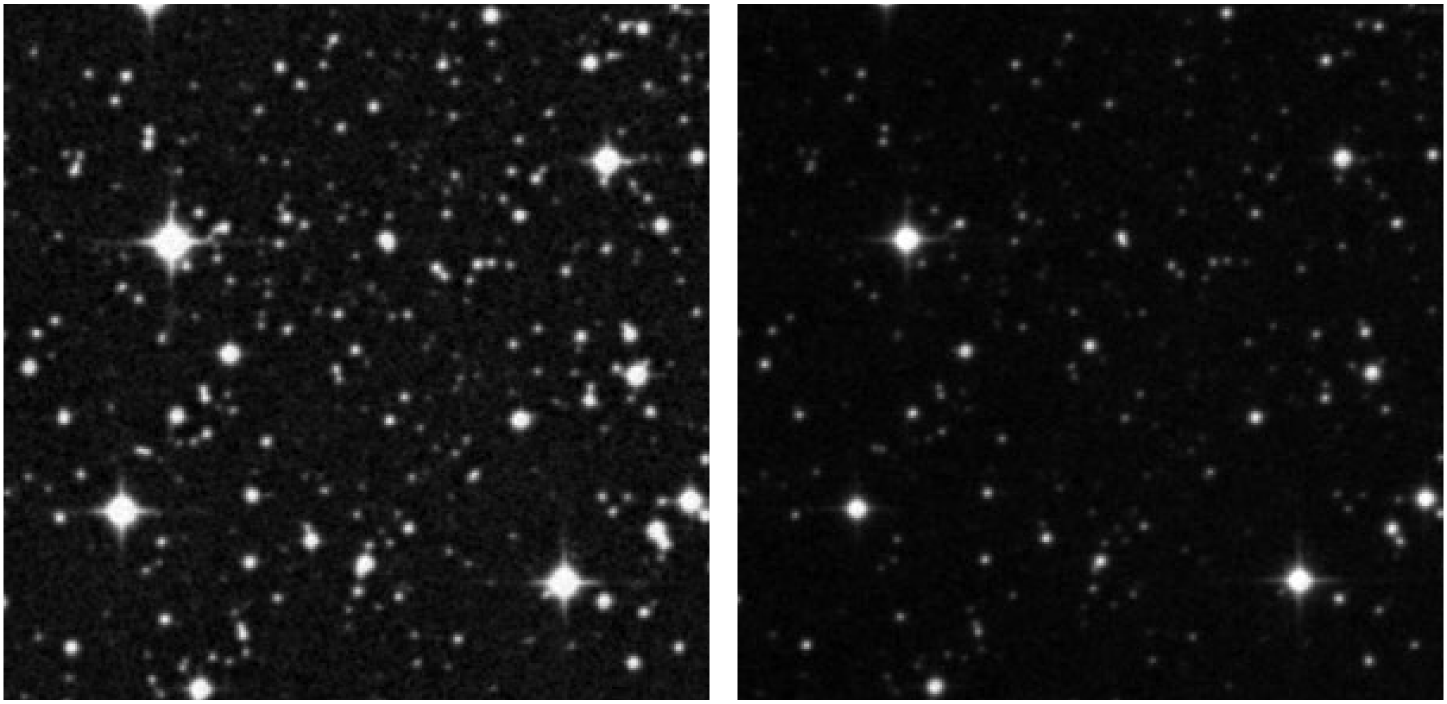


LANDSAT image of the Popigai impact crater in northern Siberia. Courtesy NASA/U.S. Geological Survey.

retrograde orbits – the kinetic energies involved in such impacts would be much greater than impacts from near-Earth asteroids, with the devastating effects accordingly being much greater.

A significant mass extinction occurred near the end of the Eocene Epoch 34 million years ago. Although this was not as large as some other mass extinctions in Earth's natural history – for example, the K-T event at the end of the Cretaceous Period 65 million years ago which included the dinosaurs, and which is discussed in a future "Special Topics" presentation – and there may have been several contributing causes, there is at least some evidence that extraterrestrial impacts played at role. A 1998 study by CalTech scientist Kenneth Farley (and which included the late planetary geologist Eugene Shoemaker among its co-authors) reported on a temporary enhancement of extraterrestrial materials in limestone deposits from that timeframe, and at least three significant impact craters – the 85-km-wide subterranean Chesapeake Bay Crater near the mouth of that estuary, the 22-km-wide Toms Canyon impact crater on the Atlantic continental shelf east of New Jersey, and the 90-km-wide Popigai Crater near the northern coast of Siberia – all date from about that same time.

The late Eocene comet shower – if there was indeed such an event – happened long enough ago such that any star that would have caused it will have long ago receded into the depths of the Galaxy. But any stars that would have passed through the Oort Cloud more recently, or that may do so at some time in the not-too-distant (astronomical) future, could, in principle, be identified. The determination of a star's motion through space requires the measurements of two components of that motion: its "transverse" motion (often referred to as a star's "proper motion")



Digitized Sky Survey images of the star field around Scholz's Star (in center). Left: Red-sensitive emulsion. Right: Infrared-sensitive emulsion. The star's enhanced brightness in the infrared image is indicative of its low mass. The field in both images is 5x5 arcminutes. Courtesy Association of Universities for Research in Astronomy (AURA).

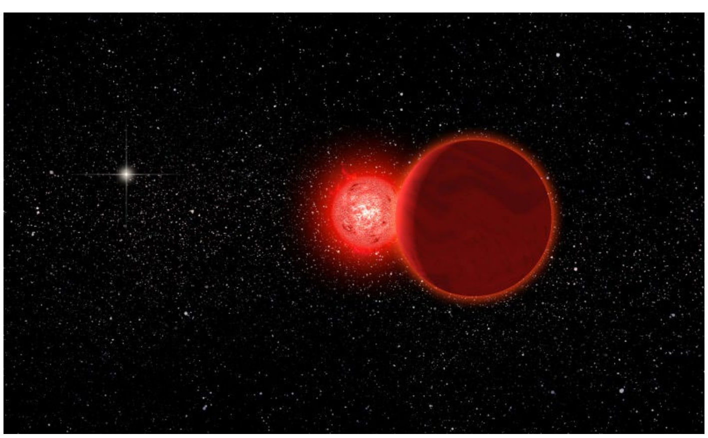
which is its motion across our line of sight against the background stars, and its "radial" motion i.e., its motion towards or away from us. A star's proper motion is determined by precise and accurate measurements of its position over a period of time – a job that is easier nowadays due to spacecraft missions like ESA's Hipparcos mission in the late 1980s and early 1990s and ESA's current Gaia mission, both of which were tasked with the precise measurements of stars' positions. A star's radial motion, meanwhile, is determined by measurements of the shifts of its spectral lines toward the blue or red end of the spectrum caused by the Doppler Effect. A star moving directly towards or away from Earth would not exhibit any proper motion but would exhibit a strong radial motion, although it's worth noting that the spectral features of low-mass stars (which constitute the majority of stars in the sun's neighborhood, and presumably the Galaxy as a whole) make such measurements more difficult than in other stars.

In 2013, while examining infrared data taken by the Wide-field Infrared Survey Explorer (WISE) spacecraft, Ralf-Dieter Scholz of the Leibniz-Institut fur Astrophysik Potsdam in Germany noted a very dim (18th magnitude), very low-mass star (0.086 solar masses) located in the constellation Monoceros (currently in our evening sky). Later studies have shown that it is actually a binary system, with the companion being a substellar "brown dwarf," and that the system is located approximately 20 light-years away. A detailed examination published in 2015 by Eric Mamajek (from the University of Rochester) and his colleagues indicates that the star – formally designated as WISE J072003.20-084651.2 or WISE 0720-0846 but which they nicknamed "Scholz's Star," a name which has stuck – passed through the outer Oort Cloud approximately 70,000 years ago. Although there is some uncertainty involved in the calculations, the best results suggest a minimum distance of about 52,000 AU. Even at the time of its closest approach the star would have been only about 11th magnitude, although since it may be subject to large flares it is conceivable that it might have occasionally, and briefly, become bright enough for naked-eye visibility.

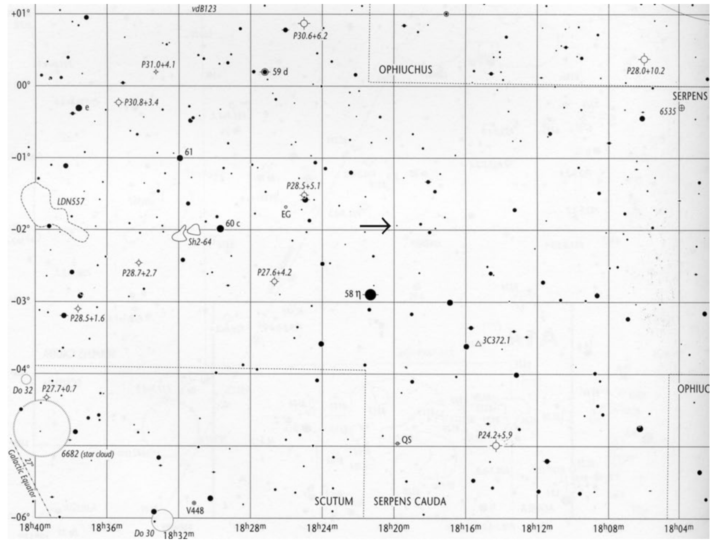
While Mamajek and his colleagues point out that Scholz's Star passed through the outer regions of the Oort Cloud, they suggest that, due to the relative distance from the sun and the system's overall low mass, there probably would not have been much of a perturbing effect on the comets within the Cloud. However, a more recent study published in early 2018 by brothers Carlos and Raul de la Fuente Marcos (of the Universidad Complutense de Madrid in Spain) suggests that the effects of Scholz's Star's passage through the Oort Cloud were stronger than that, and from their examination of the orbits of long-period comets that are already appearing we may be seeing some of the early effects. Even so, the main "comet shower" resulting from this encounter, however strong it might eventually be, is still some two million years away.

Another recent study, published late last year by Rita Wysoczanska and colleagues in Poland, utilized positional information from Gaia in an attempt to find other stars that might have passed near, or through, the Oort Cloud within the (astronomically) recent past and accordingly "kicked" specific comets into the inner solar system. They found two potential such instances: HD 7977, a 9th-magnitude sunlike main-sequence star in Cassiopeia currently 250 light-years away, passed 84,000 AU away 2.8 million years ago and may have been responsible for the appearance of Comet LINEAR C/2002 A3, and an otherwise anonymous star designated Gaia DR2 5700273723303646464 – a 12th-magnitude star in Puppis located 200 light-years away – appears to have passed 38,000 AU away 1.6 million years ago and may have been responsible for the appearance of Comet PANSTARRS C/2012 F3. Since very little is known about the star in question, the evidence for the second of these two instances is rather weak, but collectively these studies suggest that at least some of the long-period comets we see today are due to passing stars within the solar system's astronomically recent past, and that we may continue to see additional results from these encounters during the years to come.

Meanwhile, a significantly closer, and presumably much more influential, stellar passage through the Oort Cloud will be taking place in our not-too-distant (astronomically speaking) future. The star involved is Gliese 710 (also known as HD 168442), a 10th-magnitude K7 main-sequence star (about 0.6 solar masses) located 64 light-years away in Serpens Cauda near the star Eta Serpentis, and currently in our morning sky. (The "Gliese" comes from the "Gliese Catalogue of Nearby Stars" – "nearby" being within 22 parsecs, or 72 light-years – first published in 1957 by the German astronomer Wilhelm Gliese.) The possibility of a close approach of Gliese 710 to the solar system had been pointed out as early as the late 1990s, however in 2016 Filip Berski and Piotr Dybczynski in Poland used precise astrometric data from Gaia to announce that the star will pass just 13,400 AU from the sun 1.35 million years from now. At that time



Artist's conception of the two components of the Scholz's Star system during their passage through the Oort Cloud 70,000 years ago. The sun is the bright background star on the left side of the image. Courtesy Michael Osadciz/ University of Rochester.



A portion of Chart 106 from the Uranometria 2000.0 star atlas (by Wil Tirion, Barry Rappaport, and Will Remaklus), showing the location of Gliese 710 (arrowed), one degree north of Eta Serpentis. Copyright Willman-Bell, Inc.

Gliese 710 will exhibit a proper motion of almost one arcminute per year (and thus will travel the apparent diameter of the full moon in just 30 years) and should appear as bright as magnitude -3.

A star this massive passing this close to the sun will have a dramatic effect on the comets in the Oort Cloud, and in the words of Berski and Dybczynski, "We can expect that this star will have the strongest influence on the Oort Cloud objects in the next ten million years." Some of the first comets "kicked in" by Gliese 710's passage might already be making their way into the solar system by the time of its closest approach, and for the next two to three million years thereafter the nighttime skies of Earth may be filled with bright comets, and there may well be impacts from some of these within a relatively short (geologically/astronomically speaking) period of time.

Mamajek and his colleagues, and other researchers as well, estimate that stars pass through the outer regions of the Oort Cloud (100,000 AU) perhaps once every 100,000 years, on the average, although that frequency drops to around once every ten million years for approaches within 50,000 AU. Approaches to or within Gliese 710's "miss distance" would be even more rare, once every 100 million years to one billion years. Most stars that would be coming close would be of low mass, so their effects on the comets within the Oort Cloud, and eventual effects on Earth, may not be especially severe. The Gliese 710 approach does tell us, however, that "comet showers" will continue to be a part of Earth's natural history for the indefinite future, and thus any residents of Earth of those distant eras – including whatever descendants we might have – will continue to have to contend with these events at the appropriate times.

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