ICE & STONE 2020

WEEK 40: SEP. 27-OCT. 3

Presented by The Earthrise Institute

Authored by Alan Hale

Comet of the Week: The Great Comet of 1882

Perihelion: 1882 September 17.72, q = 0.008 AU

What can arguably be considered as one of the brightest and most spectacular comets of the entire 2nd Millennium was a Kreutz sungrazer, one of the most pre-eminent representatives of that class of objects that is the subject of a future "Special Topics" presentation. It was first sighted, not by astronomers, but by casual observers of the sky, including sailors aboard ship, during the first week of September 1882, with the earliest reported sightings being made on September 1 from the Cape of Good Hope and from the Gulf of Guinea. It was already a relatively conspicuous naked-eye object and numerous people spotted it over the next few days, with apparently the first astronomer to see it being William Finlay at the Cape Observatory in South Africa who independently discovered it on September 8 as he was returning home following a night's observing at the Observatory; according to his report it was already 3rd magnitude or brighter.

The famous photograph of the Great Comet of 1882 taken on November 7, 1882 by David Gill at the Cape Observatory in South Africa.

The comet was at an elongation of 30 degrees in the morning sky when first sighted, and it brightened rapidly as it approached the sun. Instead of disappearing into the dawn sky, however, its great brilliance allowed it to be kept under observation; on the 15th, when only 11 degrees from the sun, it was reported as being as bright as magnitude -2.

Shortly thereafter astronomers around the world began observing the comet in broad daylight. On the day of perihelion, September 17 – at which time the comet was between the sun and Earth and thus appeared at a high phase angle – it was so bright that all one had to do was cover the sun with an outstretched hand and it would be immediately visible. In South Africa, even while using a neutral density filter Finlay was telescopically able to follow the comet right up to the limb of the sun, suggesting a brightness as high as magnitude -14 and possibly as high as magnitude -17.

After perihelion the comet moved back over into the morning sky, although it remained visible to the unaided eye during daytime for another day or two and telescopically until the 25th. It rapidly grew a tail that was up to 25 degrees long, and that was so bright that, according to one observer, the comet and ten degrees of its tail remained visible in the dawn even after 1st-magnitude stars had already disappeared. Although it faded as it receded from the sun it did so rather slowly, being between magnitude 1 and 0 at the beginning of October and 2nd magnitude throughout the latter half of that month.

During the early days of October several astronomers began reporting individual nuclear fragments within the inner coma, and eventually as many as six of these were reported, all strung out along the comet-sun line. A rather bizarre phenomenon – somewhat unique in the history of comet observations – began to appear around the beginning of the second week of October, when several astronomers started seeing apparent "satellite" telescopic comets to the southwest of the main comet. On the morning of October 14 the American astronomer Edward Barnard reported seeing as many as six to eight of these, and possibly as many as ten to fifteen – at least one of these being as large as 15 arcminutes across – all within about six degrees of the main comet. While these were apparently short-lived phenomena, Barnard and other observers also reported that the entire comet, together with these "satellite" objects, appeared to be encompassed within a large tail-shaped "sheath"

The Great Comet of 1882 and the crescent moon on the morning of October 9, 1882, as recorded on an engraving by French astronomer Camille Flammarion.

which extended well in front of the comet and appeared to produce what we now call an "anti-tail." This entire structure disappeared by about the end of October, and it is not entirely clear just what produced it; some speculations suggest it may be due to dust released during the comet's previous perihelion passage several centuries earlier.

Most Kreutz sungrazers tend to fade away very quickly, but the Great Comet of 1882 proved to be an exception to this. It was still 3rd magnitude in December, and even when near opposition in January 1883 was still as bright as 4th magnitude with a tail 10 to 15 degrees long. It remained visible to the unaided eye until February, at which time its heliocentric distance was 3 AU, and thereafter was followed telescopically until the beginning of June, by which time its heliocentric distance had increased to 4.4 AU and it was disappearing into evening twilight.

The Great Comet of 1882 was one of several comets in the early to mid-1880s that traveled on very similar orbits, as also did the Great Comet of 1843 (a previous "Comet of the Week"). The German astronomer Heinrich Kreutz studied the various comets and concluded that they were all likely fragments of an earlier comet that had split up on a previous return, noting that the splitting of the 1882 comet provided evidence for the continuation of this process. Numerous other comets with the same basic orbit have appeared since then, and the overall story of these "Kreutz sungrazers" is the subject of a future "Special Topics" presentation. As for the various fragments of the Great Comet of 1882, at least four seem to have survived and were well enough observed to have separate orbits computed for them; their approximate orbital periods range from 670 to 950 years.

Although Comet Donati 1858 VI – next week's "Comet of the Week" – was the first comet to be photographed, it was a 100-minute exposure of the Great Comet of 1882 taken on November 7 of that year by the Director of the Cape Observatory in South Africa, David Gill, that provided a paradigm shift in the usage of astro-photography. Gill's photograph showed so many stars that many astronomers began to realize the value of photography for celestial mapping and astronomical research in general, and this stimulated the holding of the first major international astronomical conference, which was held in Paris in April 1887 and which delegates from almost 20 countries attended. From this conference sprang the first major international collaborative astronomical project, the making of an all-sky photographic map of the sky dubbed the Carte du Ciel. Although this effort was later superseded by more efficient methods, it nevertheless ranks among the more important legacies of this most spectacular of comets.

SPECIAL TOPIC: CARBONACEOUS CHONDRITES

In an earlier "Special Topics" presentation I described how meteorites are classified based upon their respective compositions. As I indicated in that presentation, the majority of known meteorites are the "stony" meteorites composed primarily of various silicates, and of these, most contain small, roughly spherical particles called "chondrules" that are primarily made up of silicates that appear to have been melted while in interplanetary space, and these meteorites are accordingly called "chondrites." There are several different types of chondrites, again based upon their respective composition, but one type in particular is of high interest in various scientific investigations. These are often porous in structure and tend to be quite dark due to a large presence of organic, i.e., carbon-containing, substances, and are accordingly called "carbonaceous chondrites."

These meteorites constitute roughly 4% to 5% of all known meteorites. There are some compositional differences between them and thus there are as many as eight or nine sub-classifications of them, but they all share the same basic qualities of being rather porous and containing significant amounts of water and organic substances. They are also very old, and in fact radiometric dating suggests they are at least as old as Earth itself; some appear to pre-date even that. Carbonaceous chondrites are thus considered as being the most primitive objects in the solar system, and are accordingly highly prized since examination of them can provide valuable insights as to the conditions that existed during the very earliest days of the solar system.

Because of their relatively porous nature and their

The Murchison meteorite, displayed at the National Museum of Natural History in Washington, D.C., is a fragment from one of the two major carbonaceous chondrite meteorites that fell in 1969. Copyright Basilicofresco, licensed via Creative Commons.

resulting fragility, many would-be carbonaceous chondrite meteorites do not survive their passages through the atmosphere, or at the very least they lose a significant part of their mass during their passage. Of those that do survive and reach the ground, they are in general quite susceptible to weathering and thus do not remain intact for very long. Although some have been found that apparently fell to the ground a long time ago – generally in pristine environments like Antarctica where erosional effects are minimized – most carbonaceous chondrites that have been well studied have come from observed meteorite falls.

Fragment from the Allende meteorite, one of the two major carbonaceous chondrite meteorites that fell in 1969. The cube is 1 cm in diameter. Courtesy Matteo Chinellato, licensed via Creative Commons.

One of the earliest observed carbonaceous chondrite meteorite falls was the Orgueil meteorite, which fell near the town of Orgueil in southern France on May 14, 1864. About 20 individual fragments were eventually collected, producing a combined mass of approximately 14 kg. The scientists examining it at the time commented on the rich content of organic substances within it, and a more recent discovery is that of a rare isotope of the gas xenon that is carried within very small and fine grains of diamond dust that are older than the solar system.

Although any carbonaceous chondrite meteorite fall is an event of high interest and the recovered meteorites the study of intense examination, there are two such meteorites that have an almost legendary stature in the study of these objects. Both of these fell a half-century ago, in the year 1969 – the same year as the first Apollo moon landings – and both have yielded significant and dramatic results from their examination.

The first of these entered Earth's atmosphere over northern Mexico on February 8 and fell to the ground

Kim Gillick and his mother Emily examine fragments they have collected of the Murchison meteorite, at the post office in Murchison, Victoria. Courtesy Gillick family/Australian Broadcasting Corporation.

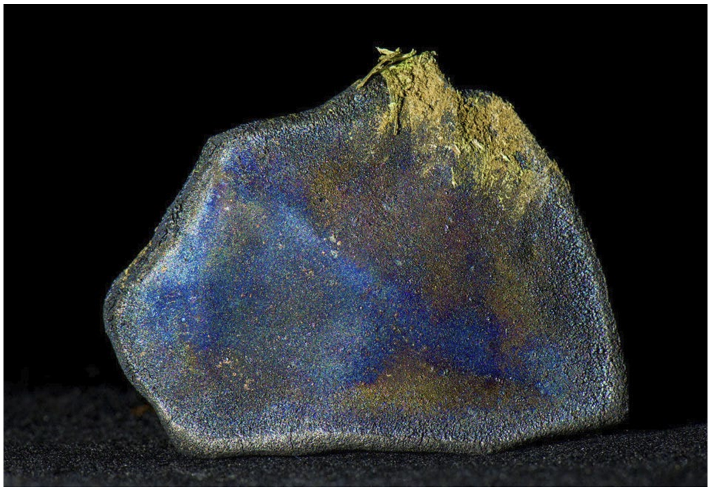
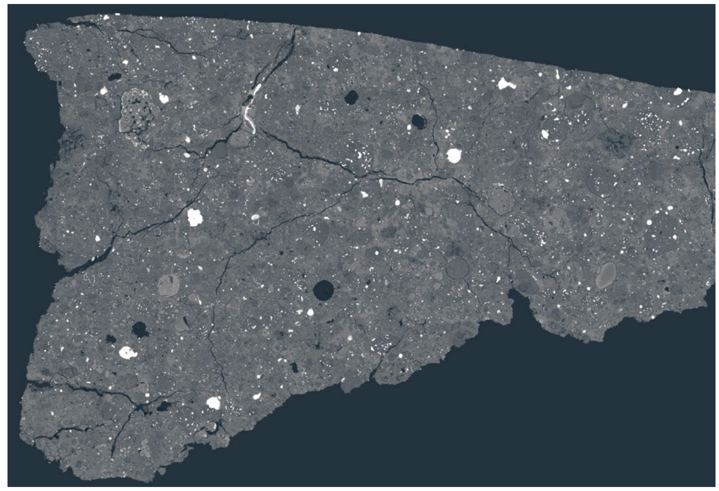
Tagish Lake in northwestern British Columbia (during the summer), the site of the Tagish Lake meteorite fall. Courtesy Richard Martin, licensed via Creative Commons.

near the village of Pueblito de Allende in southern Chihuahua. It is the largest known carbonaceous chondrite meteorite fall known; several hundred fragments have been found – the largest having a mass of 110 kg – with a combined total mass of approximately two tons. The original entering object is estimated to have been a few meters in diameter.

The Allende meteorite has been described as "the best-studied meteorite in history." It is a representative of the sub-classification of carbonaceous chondrites that have a higher content of certain metals and a lower content of certain volatile substances than other sub-classifications. The presence of rare isotopes of some of the metals, as well as radiometric dating from aluminum-26 – as discussed in a previous "Special Topics" presentation – indicates that much of the material within Allende predates the solar system, and in fact some of it appears to be from substances not presently within the solar system. Our present models about the formation of the sun and the solar system suggest that shock waves from nearby supernova explosions triggered the material within the pre-solar gas and dust cloud to start collapsing and eventually form the objects we see today, and the presence of these isotopes within Allende lends material support to this idea.

One of the Tagish Lake meteorite fragments. Courtesy Michael Holly, Creative Services, University of Alberta.

The second of the two 1969 carbonaceous chondrites came from an object which entered Earth's atmosphere over southeastern Australia during the morning daytime hours of September 28 – producing not only a bright daytime fireball but also a trail of smoke – and fell to the ground near the town of Murchison in northern Victoria. Due to a strong collection effort by local residents, including 10- and 11-year-old brothers Peter and Kim Gillick, numerous pristine fragments were quickly collected, the largest one having a mass of 680 grams and with a total combined approximate mass of 100 kg.

Fragments of two recent carbonaceous chondrites: Left: Fusion-crusted 44-mm fragment of the Aguas Zarcas meteorite that fell in Costa Rica on April 23, 2019. Courtesy Laurence Garvie/Center for Meteorite Studies/Arizona State University. Right: Scanning electron microscope image of a 1-cm fragment of the Asuka 12236 carbonaceous chondrite retrieved from the Nansen Ice Field in Antarctica in 2012. The detection of numerous extraterrestrial amino acids in this meteorite has just recently been announced. Courtesy Carnegie Institution for Science/Conol M. O'D. Alexander.

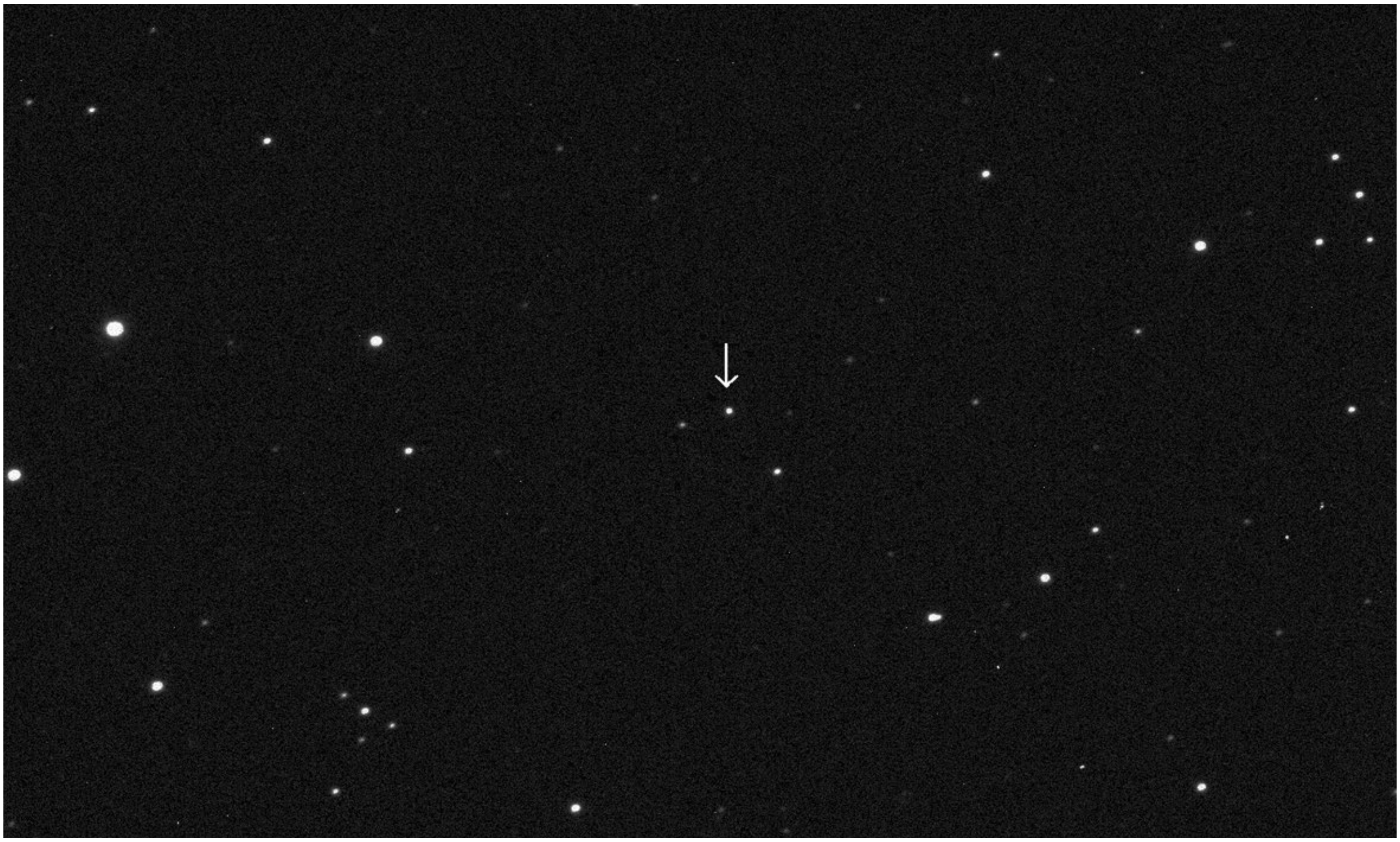
The Murchison meteorite is a representative of the sub-classification of carbonaceous chondrites that is rich in organic substances, and from a scientific perspective is widely considered as being one of the most important meteorites ever examined. Numerous organic substances have been detected within Murchison, including alcohols, sugars, and various forms of both aliphatic and aromatic hydrocarbons. Numerous amino acids – which, among other things, are utilized by life in the performance of various biological activities – have also been detected within Murchison, in fact this was the first time that amino acids had been confirmed within an extraterrestrial source. While some of these amino acids are rather common ones like glycine and alanine, many of the others are not found anywhere on Earth.

Perhaps even more dramatic has been the detection of the nucleotide bases uracil and xanthine within Murchison. Uracil, in particular, is notable in that it is one of the four nucleotide bases that make up the ribonucleic acid (RNA) molecule. It is replaced by thymine – which is uracil with a methyl group (CH3) added – as one of the nucleotide bases in the deoxyribonucleic acid (DNA) molecule. Meanwhile, just late last year ribose, a sugar molecule that makes up part of the "backbone" of RNA, was detected within a fragment of Murchison.

It can be easy to misinterpret these findings as suggesting that there might be primitive life within Murchison (and within similar carbonaceous chondrites). However, even though life – that is, "life as we know it" – utilizes amino acids and nucleotide bases, their presence alone does not automatically imply the presence of life itself. What their presence does suggest – and which is addressed in a previous "Special Topics" presentation – is that the raw materials for life, including water which is also a significant constituent of carbonaceous chondrites, were delivered to the early Earth by impacting objects like these arriving from space. Such materials would presumably have been delivered to other planets as well, although whether the existing environmental conditions on those planets permitted life to get started, and to have adapted and evolved if it did, is something about which we don't have much knowledge at this time. The topic of extraterrestrial life is explored more thoroughly in a previous "Special Topics" presentation.

Although Allende and Murchison are the two best-known and most-studied carbonaceous chondrite meteorites, there have certainly been others that have been collected and studied, including during the years that have elapsed since they fell. One of the most notable of these is the Tagish Lake meteorite, which fell onto the frozen surface of Tagish Lake in northwestern British Columbia on January 18, 2000. Over 500 fragments with a total combined mass of slightly over 10 kg have been retrieved, and because of quick detection efforts and the pristine environment in which it landed it is considered to be the best-preserved carbonaceous chondrite known to date. It appears to be somewhat in a sub-class of its own, with characteristics of two other sub-classifications as well as an unusually high water content (which is different in isotopic composition from Earth water). Amino acids have been detected within the Tagish Lake meteorite, along with gypsum and other water-bearing silicates.

An even more recent carbonaceous chondrite that fell near the town of Aguas Zarcas in Costa Rica on April 23, 2019 may eventually turn out to be as important in astronomical organic chemistry studies



Las Cumbres Observatory image of the main-belt asteroid (773) Irmintraud, the possible parent body of the Tagish Lake meteorite, taken September 16, 2020. Irmintraud is currently in the morning sky, and should reach 13th magnitude when at opposition near the end of January 2021, at which time it will be traveling westward through Cancer four degrees north of the "Beehive" star cluster M44.

as Murchison, if not even more so. Several dozen fragments of the Aguas Zarcas meteorite with a total mass of approximately 30 kg have been collected, and although analysis of these is still in its early stages, researchers have already identified numerous amino acids as well as other substances that appear to pre-date the origin of the solar system by as much as 2½ billion years. One recently-published analysis showed that the amino acid isovaline – found in various other carbonaceous chondrites but very rare in terrestrial life, and which comes in both "left-handed" and "right-handed" configurations – is distinctly more common in its left-handed form in Aguas Zarcas, consistent with results from Murchison and other carbonaceous chondrites. Since the same is true in amino acids utilized by terrestrial life, this may well have important implications in our efforts to understand how life on Earth got started.

As is the case with almost all other meteorites, carbonaceous chondrites are likely fragments of larger asteroids that have been ejected as a result of impacts upon those bodies. The parent bodies of carbonaceous chondrites are more likely to be those in the outer regions of the main asteroid belt, as in general these tend to be darker and more primitive – i.e., less "processed" – than the main belt asteroids that orbit closer to the sun. Perhaps somewhat surprisingly in this context, the large asteroid (2) Pallas has been proposed as being a source of some of the carbonaceous chondrites; although it orbits somewhat within the middle of the main asteroid belt, its spectrum nevertheless shares characteristics with the material composition of some sub-classifications of them. On the other hand, from a dynamical perspective, since Pallas has a rather high orbital inclination of 35 degrees it is not "easy" to get an impact fragment ejected from it to Earth.

The incoming track of the Tagish Lake meteorite was well enough established that astronomers could calculate an approximate pre-impact orbit for it. Their conclusion was that it had traveled on a somewhat elongated orbit that extended out to the outer asteroid belt. The suggestion has been made that a possible parent body is the main-belt asteroid (773) Irmintraud, which is a dark object spectroscopically similar to the material composition of the Tagish Lake meteorite and other carbonaceous chondrites. Although Irmintraud's orbit is near the middle of the asteroid belt, that orbit is close enough to a resonance orbit with Jupiter such that it might be gravitationally unstable, and thus at some point in the past it could have traveled farther out. From that perspective it is at least feasible that it could have been Tagish Lake's parent body.

THIS WEEK IN HISTORY

SEPTEMBER 27 28 29 30 1 2 3

SEPTEMBER 27, 1858: A British portrait painter and photographer, William Usherwood, takes a photograph of Comet Donati 1858 VI, the first photograph ever taken of a comet. No copies of Usherwood's photograph are known to exist. Comet Donati is next week's "Comet of the Week."

SEPTEMBER 27, 1990: The Hubble Space Telescope observes Comet Levy 1990c and successfully takes images of the inner coma. This was the first time that Hubble had observed a comet. Comet Levy is a previous "Comet of the Week."

SEPTEMBER 27, 2007: NASA's Dawn spacecraft is launched from Cape Canaveral, Florida. Dawn orbited the large main-belt asteroid (4) Vesta from July 2011 to September 2012 then departed for the largest main-belt asteroid, (1) Ceres, where it arrived in March 2015 and where it remains, although its mission formally ended in late 2018. The Dawn mission is described in a previous "Special Topics" presentation.

SEPTEMBER 27, 2020: The "active asteroid" (6478) Gault, a previous "Comet of the Week" which passed through perihelion early this year, will be at opposition. It is currently located in southern Pisces and traveling towards the southwest; it has been inactive during the recent past and is presently around 17th magnitude.

27 **SEPTEMBER 28** 29 30 1 2 3

SEPTEMBER 28, 1969: A brilliant daytime meteor appears over the Australian State of Victoria and falls to the ground near the town of Murchison. The Murchison meteorite is a carbonaceous chondrite, and has become one of the most studied meteorites in history. Carbonaceous chondrites are the subject of this week's "Special Topics" presentation.

SEPTEMBER 28, 2013: Images of "asteroid" (6478) Gault taken with the Dark Energy Camera (DECam) at Cerro Tololo Inter-American Observatory in Chile show Gault to be exhibiting tail activity, although this was not noticed at the time. This was the first indication of activity in this "active asteroid."

27 28 29 **OCTOBER 30** 1 2 3

SEPTEMBER 30, 1858: Comet Donati 1858 VI, one of the 19th Century's most spectacular comets, passes through perihelion at a heliocentric distance of 0.578 AU. It is next week's "Comet of the Week."

SEPTEMBER 30, 2016: After orbiting Comet 67P/Churyumov-Gerasimenko for two years, ESA's Rosetta spacecraft successfully touches down upon the comet's surface and concludes its mission. Comet 67P is a previous "Comet of the Week" and Rosetta is discussed within that presentation.

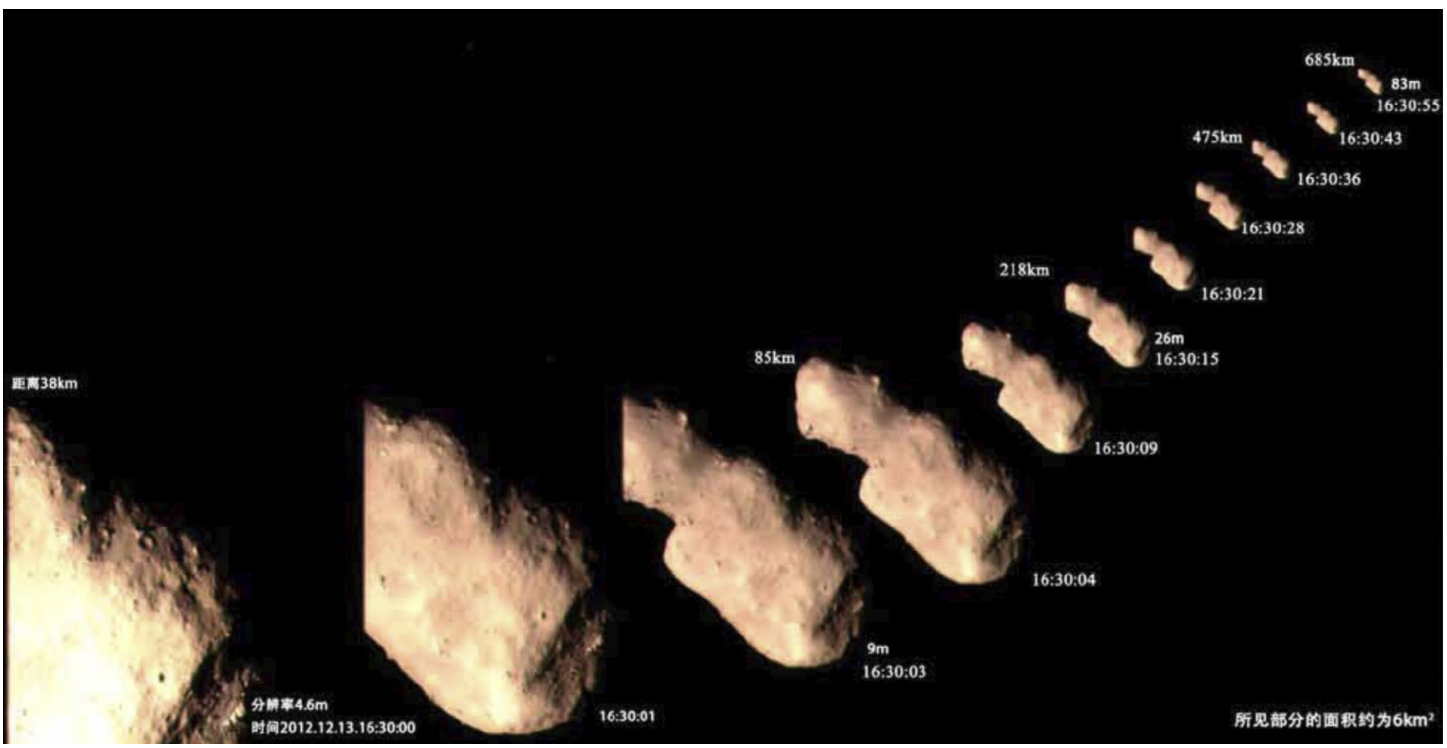
OCTOBER 1, 1847: An amateur astronomer in Nantucket, Massachusetts, Maria Mitchell, discovers a comet (old style 1847 VI, new style C/1847 T1) which passed through perihelion a month and a half later at a heliocentric distance of 0.329 AU. Mitchell would go on to become the first American female professional astronomer and taught astronomy at Vassar College for 23 years.

OCTOBER 1, 1949: An Irish engineer, Kenneth Edgeworth, publishes a paper wherein he proposes the existence of primordial "condensations" beyond Neptune's orbit that would occasionally enter the inner solar system as comets. A similar idea was independently proposed the following year by American planetary scientist Gerard Kuiper, and although these ideas lay dormant for the next few decades, they were later revived and form the genesis of the "Kuiper Belt," which has now been observationally verified. The Kuiper Belt is the subject of a previous "Special Topics" presentation.

OCTOBER 1, 1987: A team of French astronomers led by Roger Ferlet publishes a paper discussing short-term changes in the spectrum of the young star Beta Pictoris and suggesting that these may be due to comets falling onto the star. The existence of "exocomets" around Beta Pictoris was verified in early 2019 by NASA's TESS satellite. The Beta Pictoris "exocomets" are discussed in a previous "Special Topics" presentation.

OCTOBER 1, 2010: NASA's Wide-field Infrared Survey Explorer (WISE) spacecraft discovers the asteroid 2010 TK7, the first – and so far only – known example of an "Earth Trojan" asteroid. Trojan asteroids are the subject of a future "Special Topics" presentation.

OCTOBER 1, 2010: China's Chang'e 2 mission is launched from the Xichang Space Center in Sichuan, China. After spending eight months at the Earth-sun L2 Lagrangian point, Chang'e 2 departed for the Apollo-type asteroid (4179) Toutatis, which it flew by in December 2012. The Chang'e 2 mission is discussed in a previous "Special Topics" presentation.



This set of overlapping images details the flyby of China's Chang'e-2 spacecraft of the asteroid Toutatis in late 2012. Courtesy the China National Space Agency (CNSA) and the Chinese Academy of Sciences (CAS).

27 28 29 30 1 OCTOBER 2 3

OCTOBER 2, 1961: The large main-belt asteroid (2) Pallas occults the 9th-magnitude star HD 215764 in Aquarius. Successful observations of the occultation were made from South Africa and from India, making this the first successfully-observed occultation of a star by an asteroid. These events are the subject of a previous "Special Topics" presentation.

OCTOBER 2, 2017: The Pan-STARRS survey program in Hawaii discovers the comet formally designated C/2017 T2. This comet passed through perihelion this past May and became bright enough to detect with ordinary binoculars; it is a previous "Comet of the Week."

27 28 29 30 1 2 OCTOBER 3

OCTOBER 3, 1815: A meteorite falls to the ground near the village of Chassigny in northeastern France. The Chassigny meteorite has been found to have come from Mars, and is the earliest known Martian meteorite to have come from an observed fall. It differs somewhat in composition from most other known Martian meteorites and is the prototype of its own class of these objects.

OCTOBER 3, 1911: Johann Palisa at the Vienna Observatory in Austria discovers the asteroid now known as (719) Albert. Albert is an Amor-type asteroid and was only the second near-Earth asteroid to be discovered, however it was only followed for two weeks and subsequently lost until its re-discovery in 2000. Its story is told in more detail in the Week 2 "Special Topics" presentation.

OCTOBER 3, 2018: The Mobile Asteroid Surface Scout (MASCOT) rover carried by JAXA's Hayabusa2 mission successfully soft-lands on the surface of the near-Earth asteroid (162173) Ryugu, and carries out several scientific observations over the next 17 hours before its battery power runs out. The Hayabusa2 mission is discussed in a future "Special Topics" presentation.

COVER IMAGE CREDIT:

Front and back cover: Results from NASA's Wide-field Infrared Explorer, or WISE, reveal that the Jovian Trojans -- asteroids that lap the sun in the same orbit as Jupiter -- are uniformly dark with a hint of burgundy color, and have matte surfaces that reflect little sunlight. The results are illustrated in this artist's concept, showing both the leading and trailing packs of Trojans in orbit with Jupiter. Observations from WISE also confirmed the previous suspicion that there are more asteroids in the leading pack of Trojans (seen in the distance) than the trailing bunch. The data for this research come from the asteroid-hunting portion of the WISE survey, called NEOWISE.

Courtesy NASA/JPL-Caltech

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