ICE & STONE 2020

WEEK 18: APRIL 26-May 2, 2020

Presented by The Earthrise Institute

#18

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THIS WEEK IN HISTORY

APRIL 26 | 27 | 28 | 29 | 30 | 1 | 2

APRIL 26, 1803: A collection of over 3000 meteorites falls and lands near the town of L'Aigle in Normandy, France. Up until then the existence of "stones falling from the sky" had been harshly debated, but the L'Aigle meteorite fall conclusively proved that such events happen, and in effect gave birth to the study of meteorites as a serious science. Meteorites, and the role that the L'Aigle meteorites played in our knowledge about them, are the subjects of this week's "Special Topics" presentation.

26 | APRIL 27 | 28 | 29 | 30 | 1 | 2

APRIL 27, 1993: Comet Hale-Bopp C/1995 O1 appears on a photographic plate taken at Siding Spring Observatory in New South Wales. It was briefly noticed at the time but then forgotten about, until re-discovered after the comet's discovery over two years later. The comet's heliocentric distance was 13.1 AU, a record at the time for an inbound long-period comet. Comet Hale-Bopp is a future "Comet of the Week."

APRIL 27, 2020: The main-belt asteroid (560) Delila will occult the 7th-magnitude star HD 155789 in Ophiuchus. The predicted path of the occultation crosses northern Chile, southern Bolivia, central Paraguay, southern Brazil, then open waters of the southern Atlantic Ocean and finally southern South Africa.

26 | 27 | APRIL 28 | 29 | 30 | 1 | 2

APRIL 28, 1991: Minor Planet Circulars 18138-9 formally announce the naming of the main-belt asteroid (4151) Alanhale. For obvious reasons, I utilize this asteroid as an example in last week's "Special Topics" presentation about the designating and naming of asteroids.

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.

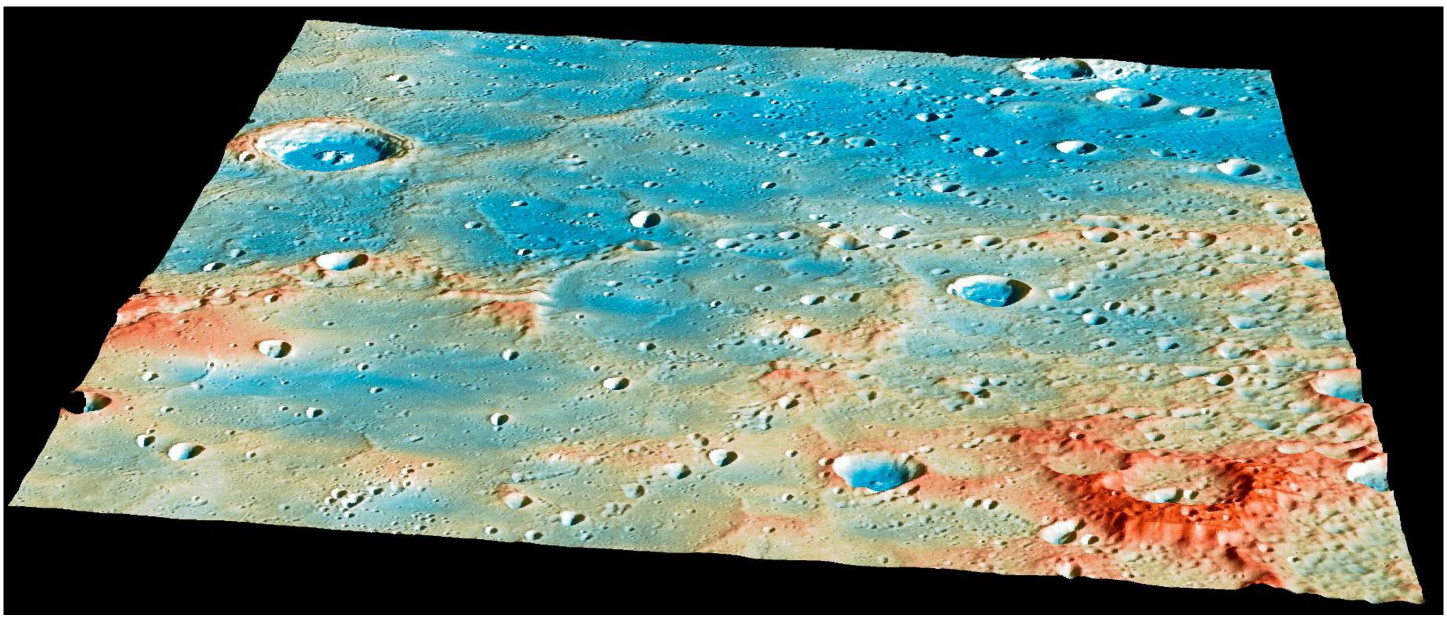
Data from NASA's NEOWISE project, based on observations made by the Wide-field Infrared Survey Explorer (WISE), have revealed the sizes and reflectivity of members of these asteroids families. The findings are helping scientists better understand how the families formed and evolved. NEOWISE is the asteroid-hunting portion of NASA's Wide-field Infrared Survey Explorer, or WISE, mission. Courtesy of NASA/JPL-Caltech.

26 27 28 **APRIL 29** 30 1 2

APRIL 29, 2020: The Amor-type asteroid (52768) 1998 OR2 will pass 0.042 AU from Earth. For two weeks it should become as bright as 11th magnitude, and radar observations have been scheduled from the Deep Space Network tracking antenna at Goldstone, California.

26 27 28 29 **APRIL 30** 1 2

APRIL 30, 2015: After orbiting Mercury for four years, NASA's MESSENGER spacecraft is deliberately impacted onto Mercury's surface. The impact should have created a crater approximately 16 meters in diameter.



This region includes the area where the MESSENGER spacecraft was predicted to collide with Mercury's surface while traveling at 3.91 kilometers per second (over 8,700 miles per hour), creating a crater 16 meters (52 feet) in diameter. Courtesy of NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

26 27 28 29 30 **MAY 1** 2

MAY 1, 1996: Comet Hyakutake C/1996 B2 passes through perihelion at a heliocentric distance of 0.230 AU. Comet Hyakutake was one of the "Great Comets" of the late 20th Century and is a previous "Comet of the Week."

MAY 1, 2000: Jeff Larsen with the Spacewatch program in Arizona discovers an asteroid, designated 2000 JW8, that is soon found to be identical to the Amor-type asteroid (719) Albert, which had been "lost" since its discovery in 1911. Albert was the last "lost" numbered asteroid to be found, and passed 0.28 AU from Earth in September 2001; it does not pass close to Earth again until 2078. Albert and other near-Earth asteroids are discussed in a previous "Special Topics" presentation.

COMET OF THE WEEK: BRADFIELD C/2004 F4

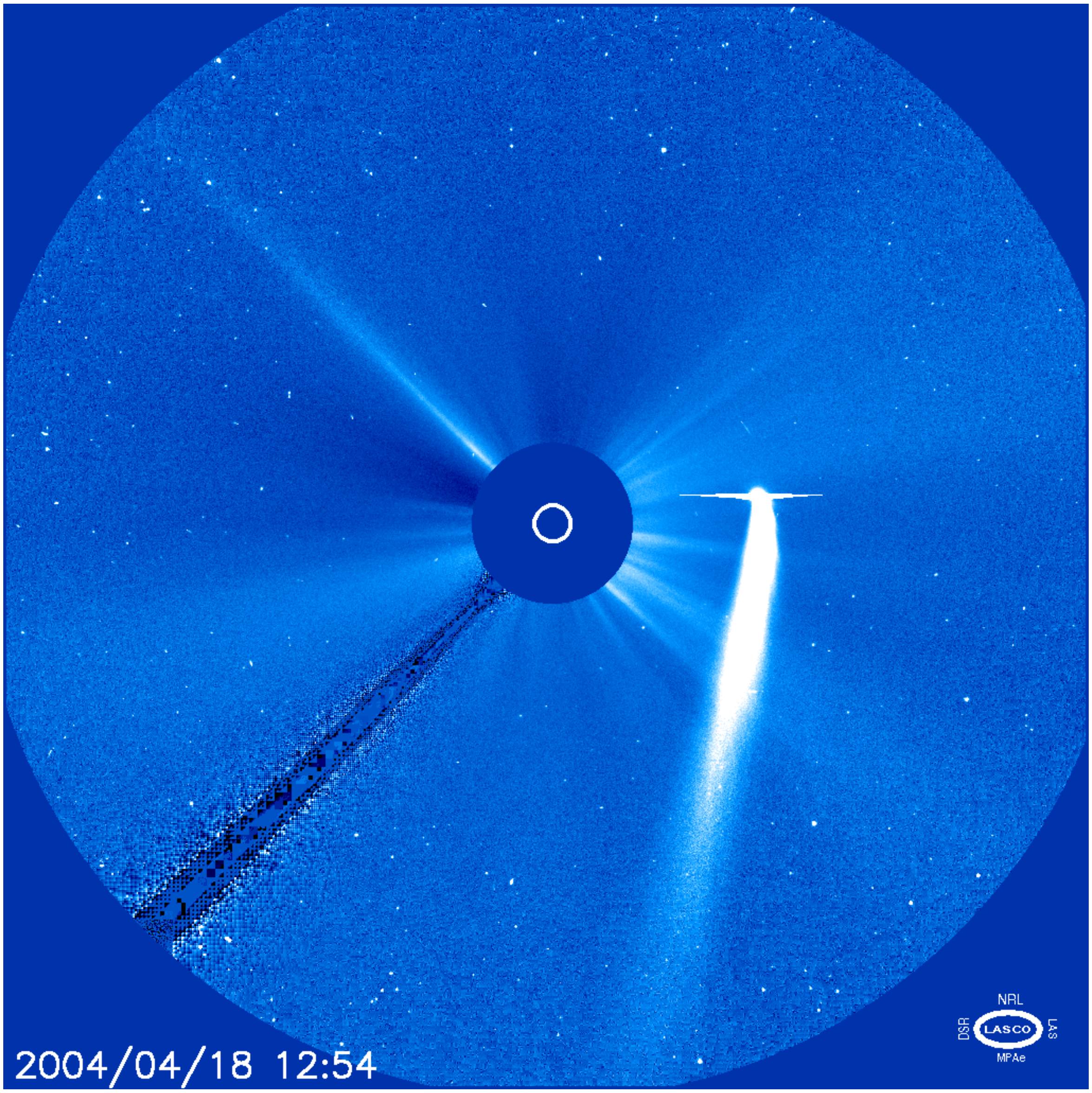
Perihelion: 2004 April 17.09, q = 0.168 AU

Photograph I took of Comet Bradfield on the morning of April 26, 2004.

One of the most legendary comet discoverers of the 20th Century was the Australian amateur astronomer William Bradfield, who resided near Adelaide, South Australia. By trade a rocket propulsion engineer with the Australian government until his retirement in 1986, Bradfield began a systematic visual comet hunting effort at the beginning of 1971, and scored his first success a little over 14 months later. He would go on to discover a total of 18 comets over the next 3½ decades, which is not only a remarkable feat in and of itself, but furthermore all of his discoveries bear his name alone. A couple of his discoveries turned out to be Halley-type comets, and meanwhile, although none of his discoveries could be considered "Great Comets," several of them did become bright enough to see with the unaided eye.

Bradfield's 18th, and last, comet was also one of his best. He discovered it low in evening twilight on March 23, 2004 as an 8th magnitude comet and successfully re-observed it the following night, however due to poor weather and its low location it eluded detection for the next two weeks before he and other observers successfully relocated it, by which time its brightness had increased to about 4th magnitude but its elongation had dropped to 17 degrees. The discovery was formally announced on April 12, and the very preliminary orbit available then indicated an imminent perihelion passage at a small heliocentric distance, and also indicated it would soon become visible in the LASCO C3 coronagraph aboard the SOlar and Heliospheric Observatory (SOHO) spacecraft.

Comet Bradfield entered the C3 field of view late on the 15th, and for the next five days put on a spectacular show in the C3 images as it traveled from south to north, and exhibited a tail up to eight degrees long. The comet was passing between Earth and the sun at the time – with the minimum distance from Earth being 0.83 AU on the 19th – and with phase angles as high as 164 degrees it undoubtedly



Comet Bradfield in the LASCO C3 coronagraph aboard SOHO on April 18, 2004. The horizontal "bar" through the coma is an artifact due to saturation of the pixels in the camera caused by the comet's high brightness. Image courtesy NASA/ESA.

exhibited a significantly enhanced brightness due to forward scattering of sunlight.

After exiting C3 Comet Bradfield began appearing in the northern hemisphere's morning sky around April 22, initially as a 4th-magnitude object deep in twilight. As it climbed higher into the morning sky over subsequent mornings it became rather easily visible to the unaided eye, and exhibited a long filmy tail for which I measured a maximum length of 8½ degrees near the end of the month. Meanwhile the comet began to fade fairly rapidly, being near 5th magnitude during the last few days of April and dropping below naked-eye visibility in early May. It remained visually detectable until late May or early June – by which time it had become quite vague and diffuse – and the final observations were obtained in mid-September, by which time it had faded to magnitude 19 or 20.

On one morning in late April I successfully observed Comet Bradfield and another comet, Comet LINEAR C/2002 T7, simultaneously with my unaided eye – the first of only two occasions in my life when I have obtained such an observation. Comet LINEAR was low in the southeastern sky at the time and soon became accessible only from the southern hemisphere (although it came back north after it had faded); curiously, observers in the southern hemisphere were able to observe it simultaneously with another naked-eye comet, Comet NEAT C/2001 Q4. This comet was still relatively bright, at 3rd magnitude, when it became accessible from the northern hemisphere in early May, and remained visible to the unaided eye for another month.

William Bradfield would not discover any additional comets, and he passed away in June 2014 at the age of 86. With all the comprehensive survey programs that are now operational and with even more expected to come on-line within the not-too-distant future, it is quite certain that we will never again encounter someone with his level of success at the art of visual comet hunting.

SPECIAL TOPIC: METEORITES

Interplanetary space in the vicinity of Earth's orbit – and, presumably, elsewhere as well – is littered with debris. Dust ejected from comets, bits and pieces of asteroids, rocks from various bodies . . . Meanwhile, Earth during its annual orbits around the sun is constantly sweeping up this debris. From the standpoint of terminology, any such object in interplanetary space is a "meteoroid," and after it enters Earth's atmosphere – becoming visible as a brief streak of light as the heat from friction with the atmosphere causes it to begin disintegrating and at the same time ionizes the air molecules around it – it becomes a "meteor." If it survives its plunge through the atmosphere and reaches Earth's surface, it becomes a "meteorite."

Two splash-formed tektites. Image courtesy Brocken Inaglory, licensed under Creative Commons.

For an object to survive its passage through the atmosphere and reach the surface as a meteorite, it must have been somewhat large, and at least somewhat dense, to begin with. (Dust grains from comets clearly would not survive this passage, but some may remain in the upper atmosphere; this is discussed in a future "Special Topics" presentation.) Meteorites have been known, and at times venerated, by many ancient cultures, although the idea of their extraterrestrial origin is a somewhat recent development. One of the earliest suggestions that meteorites might come from the sky seems to have been made by the Greek philosopher Diogenes of Apollonia in the 5th Century B.C., although the view promulgated by Aristotle a century later that these objects were terrestrial in origin became the dominant thought.

By about the beginning of the 19th Century this was still the dominant idea, with meteorites generally considered as being volcanic in origin, but thoughts were beginning to shift. In 1794 a German physicist, Ernst Chladni, published a book wherein he argued for an extraterrestrial origin of meteorites, and this was widely criticized for the most part, although a meteorite fall the following year in Yorkshire, England did start to change some thoughts. The story is often told that, following a meteorite fall near Weston, Connecticut in December 1807 that was examined by two scientists from Yale University (Benjamin Silliman and James Kingsley), then-U.S. President Thomas Jefferson – widely considered as a very intelligent man and ahead of his time – upon hearing about this, remarked "that it was easier to believe that two Yankee professors could lie than to admit than stones could fall from heaven." This appears, however, to be what would now be considered an "urban legend," although he apparently did express skepticism as to how the "stone" could have gotten into the clouds in the first place. (It should perhaps be kept in mind that the first asteroids had only been discovered within the previous few years.)

The event that really changed the human outlook on meteorites took place a few years before the Weston meteorite fall. During the afternoon of April 26, 1803, a shower of over 3000 stones fell to the ground near the town of L'Aigle in the Normandy region of France.

After a detailed study of the stones themselves as well as interviews with numerous eyewitnesses, French scientist Jean-Baptist Biot was able to demonstrate conclusively that the stones were indeed extraterrestrial in origin.

Since that time the study and analysis of meteorites has become a full-fledged scientific discipline, formally called "meteoritics." Well over a thousand meteorites have been found following observed meteors, and over 50,000 previously-fallen meteorites have been identified; some of the more notable of these are discussed in future "Special Topics" presentations.

In general, meteorites are named for the locations where they have fallen, or where they have been found. There are some locations on Earth where significant numbers of meteorites have been found; these are usually relatively pristine environments where the meteorites have been largely protected against the effects of weathering. Antarctica, in particular, has been a fertile hunting ground for meteorites, and some of the meteorites that have proven helpful scientifically, including some that are discussed in other "Special Topics" presentations, have been found there.

Just like the asteroids that, in some manner or other, produced them, meteorites come in a variety of types. Over the decades a rather detailed taxonomic system of classifying meteorites has been developed based upon composition and even extending to isotopic ratios, but in general there are three broad categories of meteorites. The overwhelming majority of them – over 90%, in fact – are primarily composed of various silicates and are thus referred to as "stony" meteorites. Approximately 5% of meteorites are metallic in composition – primarily iron, with nickel and perhaps trace quantities of other metals – and are thus usually referred to as "iron" meteorites. The remainder are a hybrid between these two broad types and are usually called "stony-iron" meteorites.

The stony meteorites themselves come in a variety of types. Most of them contain small, roughly spherical particles called "chondrules" that are primarily made up of silicates that appear to have melted while in interplanetary space and then incorporated into the larger rocks. These meteorites, called "chondrites," come in a variety of classifications depending upon their elemental and isotopic composition, and are believed to be among the oldest of the meteorites. One type of chondrite, the "carbonaceous chondrite" so called due to the presence of significant amounts of organic, or carbon-containing, substances, is of special interest in the study of Earth's formation and natural history, and is the subject of its own future "Special Topics" presentation.

The remaining stony meteorites do not contain

Various types of meteorites. TOP: Chondrite. A fragment of the Marilia meteorite that fell in Brazil in 1971. MIDDLE: Carbonaceous chondrite. A fragment of the Murchison meteorite that fell in Victoria in 1969. Courtesy New England Meteoritical Services. BOTTOM: Iron meteorite: The Murnpeowie meteorite, discovered in the South Australian outback in 1909. Courtesy Basilicofresco, licensed under Creative Commons.

chondrules and thus are called "achondrites." There are several varieties of these as well, and some of these are of special interest due to their apparent place of origin. Some of them have elemental and isotopic abundances very similar to those of rocks brought back from the moon by the Apollo astronauts, and thus appear to have come from the moon. (The first known example is the meteorite designated ALH A81005, discovered in the Allan Hills region of Antarctica in January 1982.) Several other achondrites have elemental and isotopic compositions similar to that of Mars' atmosphere as has been measured by spacecraft on Mars' surface, and thus appear to have come from that planet; the first known example of these (determined retroactively, of course) is the Chassigny meteorite that fell in France in October 1815. The best-known "Martian meteorite" is the one designated ALH 84001 (also found in the Allan Hills region of Antarctica) and it is discussed in its own future "Special Topics" presentation. For both the lunar and Martian meteorites, impacts on those bodies ejected some rocky debris with enough force that they were able to escape into interstellar space and into orbit around the sun, eventually to be swept up by Earth at some date possibly millions of years in the future.

Widmanstatten pattern on a fragment of the Seymchan meteorite found in the Magadan district of Russia in 1967. Courtesy Basilofresco, licensed under Creative Commons.

Some of the other achondrites have elemental and/or isotopic abundances similar to those that have been spectroscopically determined for various asteroids, and it is accordingly believed that these asteroids are the "parent bodies" of these meteorites. Over a majority of achondrites, in fact, have abundances similar to those in the main-belt asteroid (4) Vesta, and thus these meteorites likely originated from Vesta. Images taken by the Dawn mission when it orbited Vesta between 2011 and 2012 have revealed two large impact craters – named Rheasilvia and Veneneia – near Vesta's south pole, and the impact events that created those craters are believed to be what ultimately led to these meteorites. The process was likely not direct but instead involved the creation of what is called the "Vesta family" of asteroids (from which the meteorites eventually came); this is one of the "asteroid families" covered in a future "Special Topics" presentation.

One other group of "space rocks" that warrant mentioning are the "tektites." These are small, "glassy" objects that were originally believed to be another type of meteorite. However, analysis has now shown that they are terrestrial in origin, being formed when local rocks and sediment are melted by the heat generated by an impacting meteorite and then deposited over "strewn fields" that may be many tens of km, perhaps even hundreds of km, from the impact site. Most tektites have been found in one of a handful of specific strewn fields and have been found to be associated with specific impact events. For a time there was a school of thought that proposed that at least some tektites might be lunar in origin, but this is not generally accepted today.

The main-belt asteroid (4) Vesta as imaged by the Dawn spacecraft on July 24, 2011. The large protuberance near the south pole is the central peak of the Rheasilvia impact crater, which contributes to the overall misshapen appearance. Image courtesy NASA.

When iron meteorites are etched in acid, fine-lined criss-crossed features called a "Widmanstatten pattern" – so named after the Austrian scientist Alois von Beckh Widmanstatten, although they were first reported a few years earlier by an English mineralogist, William Thompson – appear. These are formed from iron-nickel alloys at warm temperatures, albeit below the alloys' melting points, that then cool at a very slow rate (i.e., over millions of years). By measuring the amount of this cooling it is then possible to determine the age of the meteorite in question.

Another form of meteorite dating, which can be applied to almost all the various types of meteorites, involves the radioactive isotope aluminum-26, which has a half-life of 717,000 years. In space this can be created by a steady bombardment of cosmic rays, and when a meteorite's parent body breaks up the resulting meteoroids are exposed to these cosmic rays which cause them to become saturated with aluminum-26. Once the meteorite falls to Earth, however, this process ceases, and the meteorite can then be dated radiometrically by the amount of aluminum-26 that remains.

One of the fragments of the L'Aigle meteorite.

Ugandan boy (unidentified) holding the fragment of the Mbale meteorite that struck him on his head, August 14, 1992. Courtesy Dutch Meteor Society.

Throughout history there have been occasional accounts of people being struck and even killed by meteorites, although it is difficult to evaluate the validity of such accounts that may have occurred millennia ago. On November 30, 1954 a meteorite crashed through the roof of a house near Sylacauga, Alabama and struck a 34-year-old woman, Ann Elizabeth Hodges, while she was sleeping on a couch. (She suffered a large bruise on her side but was otherwise OK.) One fragment of the Nakhla meteorite – a Martian achondrite, incidentally – that fell over Egypt in June 1911 supposedly struck (and apparently killed) a dog, although there does not seem to be any corroborating evidence that supports this. Meanwhile, on August 14, 1992 a small (3 gram) fragment of a meteorite fall over Mbale, Uganda struck a boy in the head; he was uninjured in part because of the fact that the fall was cushioned by the leaves of a banana tree under which he was standing.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