ICE & STONE 2020

WEEK 9: FEBRUARY 23-29, 2020

Presented by The Earthrise Institute

#9

Authored by Alan Hale

THIS WEEK IN HISTORY

FEBRUARY 23, 1988: David Levy obtains the final visual observation of Comet 1P/Halley during its 1986 return, using the 1.5-meter telescope at Catalina Observatory in Arizona. The comet was located 8.0 AU from the sun and appeared at 17th magnitude.

FEBRUARY 24, 1979: The U.S. Defense Department satellite P78-1 is launched from Vandenberg Air Force Base in California. One of P78-1's instruments was the SOLWIND coronagraph, which detected ten comets between 1979 and 1984, nine of which were Kreutz sungrazers and the first of these being the first comet ever discovered from space. SOLWIND continued to operate up until the time P78-1 was deliberately destroyed in September 1985 as part of an Anti-Satellite weapon (ASAT) test. The first SOLWIND comet is a future "Comet of the Week" and Kreutz sungrazers as a whole are the subject of a future "Special Topics" presentation.

FEBRUARY 25, 1976: Comet West 1975n passes through perihelion at a heliocentric distance of 0.197 AU. Comet West, which is next week's "Comet of the Week," was one of the brightest comets that appeared during the second half of the 20th Century, and I personally consider it the best comet I have ever seen.

COVER IMAGES CREDITS:

Front cover: Three impact craters of different sizes, arranged in the shape of a snowman, make up one of the most striking features on Vesta, as seen in this view from NASA's Dawn mission. In this view the three "snowballs" are upside down, so that the shadows make the features easily recognizable. North is to the lower right in the image, which has a resolution of 230 feet (70 meters) per pixel The image is composed of many individual photographs taken between October and December 2011 by Dawn's framing camera. The largest of the three craters, Marcia, has a diameter of about 40 miles (60 kilometers). Courtesy NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

Back cover: This enhanced-color view from NASA's Dawn mission was imaged on September 20, 2012. It shows an unusual 'pitted terrain' on the floors of the crater named Cornelia on the giant asteroid Vesta. Courtesy NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/JHUAPL

23 24 25 26 **FEBRUARY 27** 28 29

FEBRUARY 27, 1826: An Austrian army officer, Wilhelm von Biela, discovers a comet which is soon found to be identical to comets that appeared in 1772 and in 1805-06. Comet 3D/Biela, as this comet is now known, was last week's "Comet of the Week" and is a classic example of a comet's splitting into two and then disintegrating. It is the parent comet of the Andromedid meteor shower in November.

FEBRUARY 27, 1843: The Great Comet of 1843 passes through perihelion at a heliocentric distance of 0.006 AU. It was a Kreutz sungrazer and is a future "Comet of the Week;" Kreutz sungrazers as a whole are the subject of a future "Special Topics" presentation.

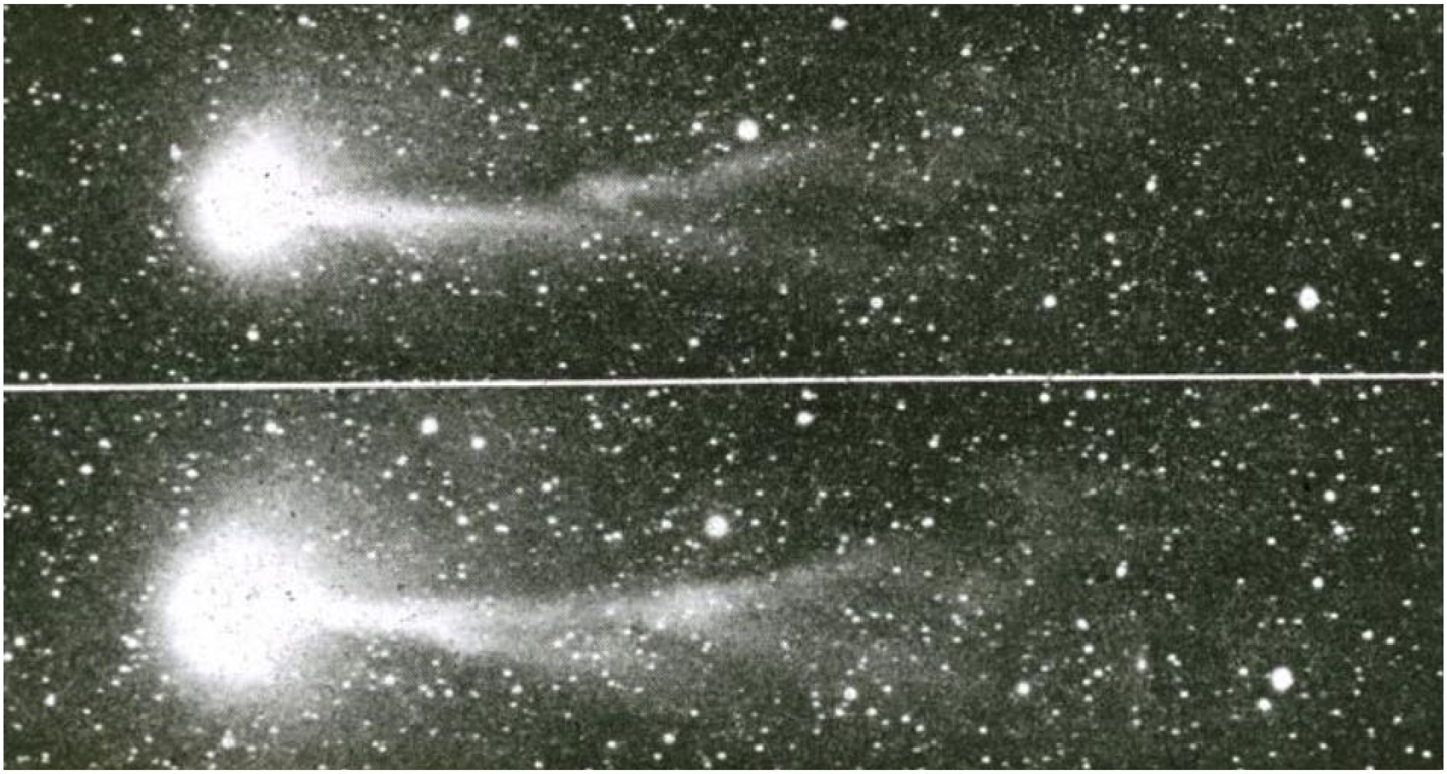
23 24 25 26 27 **FEBRUARY 28** 29

FEBRUARY 28, 1998: Comet 55P/Tempel-Tuttle passes through perihelion during its most recent return at a heliocentric distance of 0.977 AU. Comet Tempel-Tuttle is the parent comet of the Leonid meteor shower in November, which has produced some of the strongest showers in recorded history. The relationship between comets and meteor showers is the subject of a future "Special Topics" presentation.

***THERE ARE NO CALENDAR ENTRIES FOR FEBRUARY 26 AND 29.**

COMET OF THE WEEK: WHIPPLE-FEDTKE-TEVZADZE 1942G

Perihelion: 1943 February 6.72, q = 1.354 AU



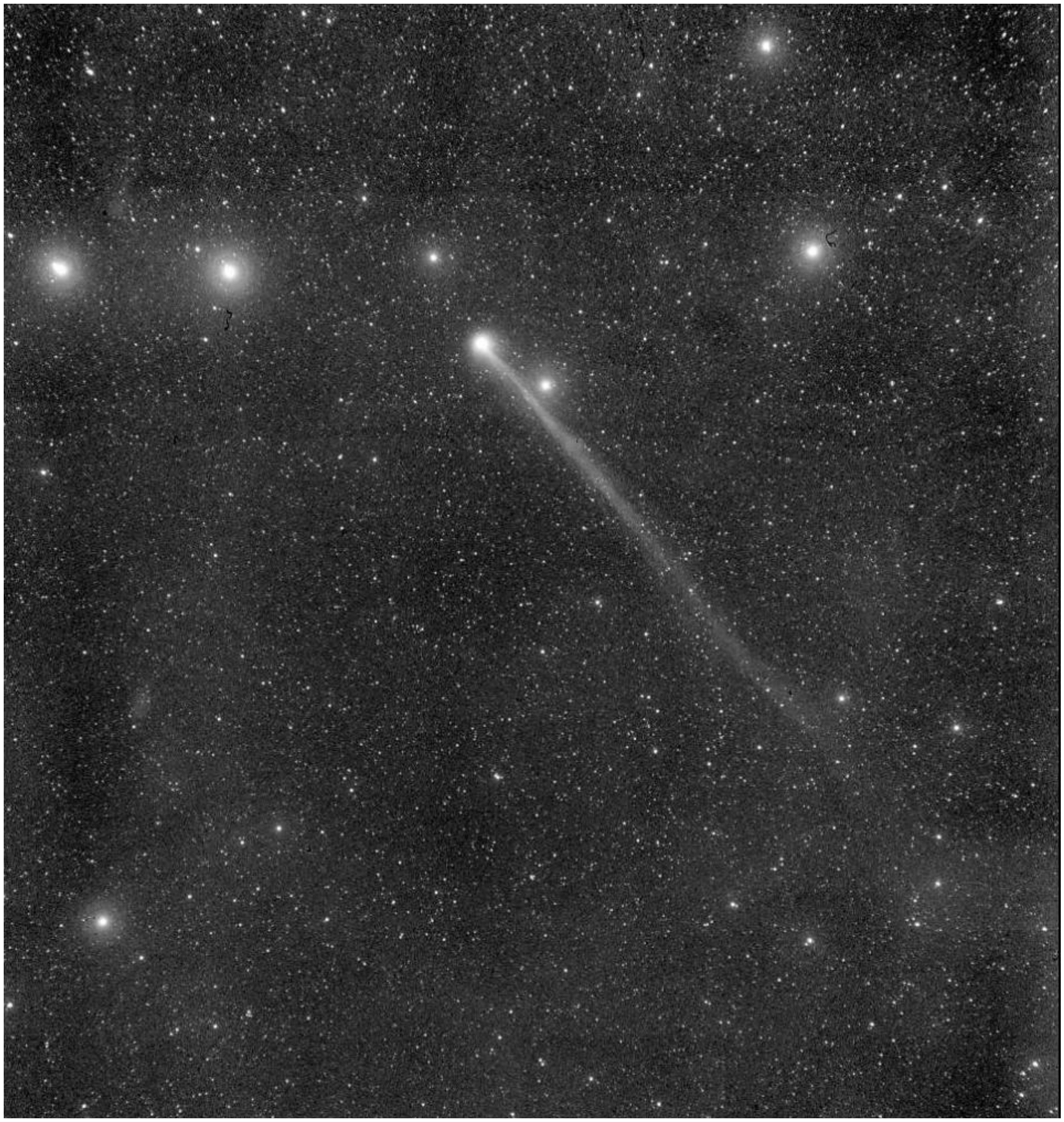
Activity in the ion tail of Comet Whipple-Fedtke-Tevzadze on March 28 (top) and 29 (bottom), 1943. The photographs were taken by Cuno Hoffmeister at Sonneberg Observatory in Germany.

The name of Fred Whipple is legendary in cometary astronomy. He spent several decades as an astronomer and professor at Harvard University, and is best known for developing what he called the "icy conglomerate" model of a comet's nucleus (more commonly referred to as the "dirty snowball") in a series of papers in the mid-1950s; spacecraft missions decades later verified the essential correctness of his model. (This will be the subject of next week's "Special Topics" presentation.) Among other accomplishments, he also invented the "Whipple Shield" that protects spacecraft – including crewed platforms like the International Space Station – from micrometeoroid impacts.

During his early years at Harvard Whipple was involved in photographic patrol work, primarily of meteors. While engaged in this effort, between the early 1930s and early 1940s he discovered one asteroid – (1252) Celestia, which he named after his mother – and six comets. One of these is the short-period object now known as 36P/Whipple which, primarily as a result of a close approach to Jupiter in 1981, now travels in an orbit with a period of 8.4 years and the rather large perihelion distance of 3.0 AU which causes it to remain faint. It will pass through perihelion at the end of May.

Whipple discovered his last, and best, comet on a patrol photograph that had been taken on December 8, 1942, and later he was able to identify it on earlier photographs extending as far back as November 5. The various nations of the world were at the time embroiled in World War II, and thus communications between nations could be quite difficult; while the comet was initially referred to in the U.S. as "Comet Whipple," word of independent discoveries elsewhere eventually came to light, including ones by Carl Fedtke at Konigsberg Observatory in East Prussia (now Kaliningrad in Russia) on December 11 and by G.A. Tevzadze at the Abastumani Observatory in the Caucasus Mountains (in what is now Georgia) on December 15. Even the preliminary discovery designation caused difficulties: the comet was called "1942f" in the U.S. but "1942g" in Europe, and several months elapsed before this could be straightened out. (For what it's worth, the comet's old style perihelion designation is 1943 I and its new style designation is C/1942 X1.)

The comet remained well placed for observation, especially for observers in the northern hemisphere, for the next several months, and was nearest Earth



Comet Whipple-Fedtke-Tevzadze and the Big Dipper on February 26, 1943, as photographed from Harvard's Oak Ridge Observatory. The tail is longer and more impressive on blue-sensitive photographs like this one than it would have been visually. Courtesy Harvard University.

(0.43 AU) in late January. Initially around 9th or 10th magnitude around the time of its discovery, it brightened unexpectedly rapidly, already being brighter than 6th magnitude by mid-January and being close to 4th magnitude by the end of that month. It then began fading, as expected, and had dropped to 5th magnitude by the second week of February, however it then underwent an unexpected surge in brightness, being near magnitude 3 ½ during the latter days of February. It was crossing the "bowl" of the Big Dipper at that time and thus was amenable to casual observations; for example, the May 1943 issue of "Sky & Telescope" contains a dramatic first-hand account of an "independent" discovery by a U.S. Navy Quartermaster, Francis Wilmot, from aboard ship in the Atlantic Ocean.

Afterwards, the comet began fading again, dropping below naked-eye visibility in early April, although it exhibited occasional small and short-lived brightness increases during that period. It faded more "normally" after that, with the last observations being obtained in early August.

Comet Whipple-Fedtke-Tevzadze was a very dust-poor comet and thus didn't exhibit much of a dust tail, but it did exhibit a rather long and distinct ion tail, which reached a maximum visual length of about six degrees but extended up to almost 20 degrees on photographs. This tail also exhibited various signs of structure and activity, including at least one disconnection event in late March. At the same time, photographs appeared to indicate a small secondary nucleus, with the best calculations indicating a splitting date around March 9 – curiously, a few weeks after the major brightness increase that often accompanies fragmentation of a comet's nucleus. In any event, the near-nucleus activity and the goings-on within the ion tail appear to be unrelated to each other, which serves to highlight the wide range of independent physical and chemical processes that take place within comets as they make their passages around the sun.

SPECIAL TOPIC: GREAT COMETS

Historical "Great Comets." Left: The "Great Comet" that appeared in November 1618 (one of three bright comets that appeared that year), as painted by Dutch painter Adriaen Pietersz van de Venne. Right: The tails of Comet de Chesaux rising above the horizon on the morning of March 7, 1744. It is possible that these are the tips of "synchronic bands" of a more extensive dust tail.

Few, if any, sights in the nighttime sky are more impressive than that of a bright, long-tailed comet. It is little wonder that our ancestors of just a few centuries ago, who had little idea of what they were actually seeing, were amazed and perhaps even terrified of the sight, and even today the appearance of a bright comet gathers wide notice amongst the general public.

The traditional practice of naming comets after their discoverers did not start until the mid-18th Century. Prior to that, comets were primarily known as the "Comet of <the year of their appearance>" or, perhaps more commonly, the "Great Comet of <the year of their appearance>." Even after the naming convention started, bright comets would sometimes spring into view seemingly out of nowhere, and the moniker "Great Comet of <year>" still appears in the list of observed comets. Nowadays almost all comets are formally named for their discoverers – although, more often than not, today the discovering entity may be a survey program rather than a specific person or persons – but, even so, a comet bright enough to rate the title may still be referred to informally as the "Great Comet of <year>."

There is no formal definition as to what constitutes a "Great Comet," and even any informal definition must to some extent be subjective. Still, a good working definition might be any comet that becomes bright and/or impressive enough such that casual sky-watchers who were previously unaware of its existence would notice it. Indeed, prior to the invention of the telescope in the early 17th Century, just about any comet that people observed would have had to meet this criterion, and thus all comets that were seen before that time would of necessity be "Great Comets."

Given this working definition, it is appropriate to consider just what factors go into making a comet a "Great" one. As is true for just about anything in life, there is no "one size fits all" set of factors, and some "Great" comets may exhibit one or more factors while other comets may exhibit others – and not all comets that exhibit the factors end up being "Great" ones. The overall deciding factor, again, is the appearance it puts on in the nighttime – and sometimes even the daytime – sky.

Certainly one such factor is a comet's intrinsic, or "true" brightness; all other factors being equal, a large comet would be expected to become brighter than a smaller one. The term usually used with comets is "absolute magnitude," which is defined as the apparent magnitude it would have if it were viewed from a distance of 1 AU from both the sun and the earth. On the surface this is a straightforward mathematical calculation, at least when it comes to geocentric distances, which is simply an application of the inverse-square brightness law. With distance from the sun, however, not all comets behave the same when there are located at varying distances, and usually some assumptions – which may or may not necessarily be valid in all cases– need to be utilized. What is usually done in practice is that an

A more recent "Great Comet:" Comet Hale-Bopp on April 1, 1997, from the deck of my former residence in Cloudcroft, New Mexico.

inverse-nth (where "n" is generally some number higher than 2) brightness behavior is applied. For most cases "n" is usually assumed to be 3 or 4, as this tends to encompass the behavior of the majority – although certainly not all – comets that have been studied.

Comet Hale-Bopp, which appeared in 1997, turns out to have a high intrinsic brightness, with an absolute magnitude – depending upon the assumed value of "n" – being as bright as -1. Of all the comets that have been observed in history, this is the second-brightest absolute magnitude ever seen, which goes a significant way towards explaining why Hale-Bopp was a "Great" comet – and why it was bright and visible for as long as it was.

The brightest comet, intrinsically, ever recorded was Comet Sarabat in 1729, which – again, depending upon the assumed value of "n" – had an absolute magnitude as bright as -3. However, that comet had a perihelion distance of slightly over 4 AU – as opposed to 0.9 AU for Hale-Bopp – and thus was never brighter than 3rd or 4th magnitude.

Clearly, then, another factor is a comet's perihelion distance. The closer a comet comes to the sun, the more activity it – normally – exhibits, and thus the brighter it would be expected to become, all other things being equal. (The increased level of activity is the primary reason that "n" is usually assumed to be greater than 2 in calculations of a comet's absolute magnitude.) The Kreutz sungrazers, with perihelion distances less than 0.01 AU, take this to an extreme, and in fact members of this group with just modest absolute magnitudes have become quite bright and "Great" – for example, Comet Lovejoy C/2011 W3.

Smaller perihelion distances can also affect the potential "Great"-ness of comets in other ways. The increased solar heating at smaller heliocentric distances puts greater stress on a comet's nucleus, which in some cases can lead to splitting of that nucleus. This in turn exposes previously-hidden regions of cometary ice to sudden sunlight, and often leads to an upsurge in brightness. Comet West 1975n split into four separate fragments as it passed through perihelion in early 1976, and this made a significant contribution to the brilliant display that the comet put on afterwards.

On the other hand, especially if a comet's nucleus is small to begin with, the solar heating at small heliocentric distances can cause that nucleus to disintegrate. Comet ISON in 2013, with a perihelion distance of just over 0.01 AU, had the potential to put on a brilliant display after perihelion, but its nucleus

One comet that didn't quite make "Great Comet" status. Comet PANSTARRS C/2011 L4 and the two-day-old crescent moon on the evening of March 12, 2013, from Cerrillos, New Mexico. This photo is an approximate cross between its naked-eye appearance and its appearance in binoculars. Courtesy Peter Lipscomb.

evaporated as it rounded the sun and there was nothing left to see afterwards.

A comet's distance from Earth can also affect its potential "Great"-ness, as even a more "ordinary" comet might become "Great" if it passes close enough to Earth. Comet Hyakutake in 1996 passed just over 0.1 AU from Earth as it was inbound to perihelion, which not only caused it to brighten to magnitude 0 at the time but it also presented Earth with a broadside view of its tail which created an extraordinary apparent length – at least 70 degrees or longer.

The composition of a comet's nucleus is another factor that can determine how "Great" it might become. For example, a comet with a high fraction of ices and other volatile substances would likely exhibit more activity as it approaches perihelion than the "average" comet, which in turn might cause it to brighten more rapidly than expected. On the other hand, the ion tail created by the sublimated ices is brightest in the blue end of the visual spectrum, and while it may be quite impressive on blue-sensitive film or detectors, human eyes are not especially sensitive to blue wavelengths and thus a comet's ion tail is normally not too impressive visually. The long tail that Comet Hyakutake exhibited when it passed by Earth in 1996 was an ion tail that was impressive when viewed from dark rural sites but significantly less impressive when viewed from sites with even moderate light pollution.

Dust from a comet, meanwhile, "shines" by reflected sunlight, to which human eyes are much more sensitive. Thus, a comet with a high dust content, and which can produce a significant dust tail, will appear more impressive visually than an otherwise similar comet with only an ion tail. Comet West in 1976, Comet Hale-Bopp in 1997, and Comet McNaught in 2007 all had prominent dust tails, and accordingly all three were spectacular objects.

If a comet with a high dust content is between the sun and Earth or, in other words, if a comet is viewed at a high "phase" angle (the angle Earth-comet-sun), the dust in its coma and tail may exhibit a phenomenon known as "forward scattering of sunlight." Dust particles of these sizes preferentially scatter sunlight in a forward direction; one common example of this occurs if one is driving towards the sunset with a dusty windshield. With comets, forward scattering can increase a comet's brightness, sometimes quite dramatically, during those periods when phase angles are high. Comets West and McNaught both exhibited phase angles in excess of 140 degrees for a time and thus their respective brightnesses were significantly enhanced as a result.

The viewing geometry under which we observe a comet can certainly affect the display it puts on in our skies. A comet might become quite bright in terms of its total magnitude but if it can only be viewed at a low altitude in twilight it may not become especially impressive, whereas a dimmer comet that is viewed higher up in a dark sky might become rather spectacular. Comet PANSTARRS C/2011 L4 became as bright as magnitude 1.5 when it passed through perihelion in March 2013, and moreover was a rather dusty comet with a bright dust tail, however it remained on the far side of the sun from Earth – and consequently there was no brightness enhancement due to forward scattering – and was buried in twilight at an elongation of only 15 degrees when it was brightest, and thus never became what most observers might consider a "Great" comet despite its high brightness.

One additional factor that can affect a comet's potential "Great"-ness is its dynamical history. Comets that have remained in the Oort Cloud since the formation of the solar system may have acquired a thick organic "crust" overlaid by a mix of volatile substances, and when an incoming comet from the Oort Cloud starts to experience solar heating for the first time this outer layer of volatiles may begin sublimating at a rather large heliocentric distance and create the impression of a higher intrinsic brightness than the comet actually possesses. Once this is completed, however, the organic crust causes the comet to decrease its activity significantly, until the increased solar heating at smaller heliocentric distances starts to break apart this crust and expose the volatiles underneath. On the other hand, a comet that has been around at least once before and that no longer possesses this organic crust – or, in other words, has been "broken in" – will generally exhibit a more accurate level of its true intrinsic brightness as it is inbound to subsequent perihelion passages.

If a first-time visitor from the Oort Cloud is discovered during its initial period of activity, this can lead to expectations that it might become significantly brighter than it actually ends up becoming – leading to, among other things, disappointment amongst the viewing public. The best-known example of this is Comet Kohoutek in 1973 which in part because of its small perihelion distance (0.14 AU) led to early predictions that it would become the "Comet of the Century." Although it did become moderately bright as viewed from dark rural sites, Comet Kohoutek was significantly less impressive than these predictions, and is widely considered as a "fizzle." (To be sure, other potential "Great Comets" that were first-time visitors from the Oort Cloud have performed even more poorly.) It is usually possible to tell after two or three months of positional data whether or not a newly-discovered long-period comet is a first-time visitor from the Oort Cloud, and if it is found to be such then expectations can be downsized accordingly.

Another comet that didn't quite make "Great Comet" status. Comet Kohoutek 1973f on the evening of January 7, 1974. Photograph courtesy Dennis di Cicco.

All of the above factors go into determining whether or not a comet becomes a "Great" one. While just about all of these can, to some extent at least, be determined ahead of time, still, it is the comet's actual performance that ultimately determines if it is indeed a "Great" comet. Despite everything we have learned about them, they can still be notoriously unpredictable, and essentially all we can do is see what a comet actually does. To quote David Levy, "Comets are like cats; they have tails and do exactly what they want." Or, to quote comet scientist Fred Whipple, "If you must bet, bet on a horse, not on a comet!"

Since I first started observing comets in early 1970 I have seen four comets that I, and most other comet observers, would consider to be "Great" comets. These are:

Comet Bennett in 1970: moderately high intrinsic brightness, high dust content, not a first-time Oort Cloud visitor.

Comet West in 1976: high dust content, small perihelion distance, fragmenting of nucleus, high phase angle, not a first-time Oort Cloud visitor.

Comet Hyakutake in 1996: close approach to Earth, good viewing geometry, not a first-time Oort Cloud visitor.

Comet Hale-Bopp in 1997: high intrinsic brightness, high dust content, not a first-time Oort Cloud visitor.

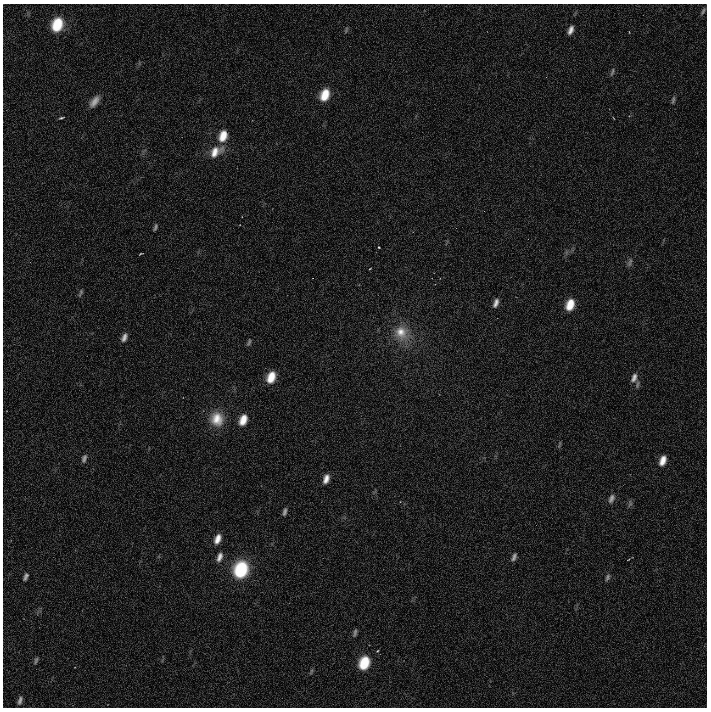
In addition, since Comet Hale-Bopp there have been two more "Great Comets" that were pretty much exclusively visible from the southern hemisphere (although Comet McNaught was visible in daytime from both hemispheres around perihelion passage). **Comet McNaught in 2007:** high dust content, small perihelion distance, high phase angle.

Comet Lovejoy in 2011: very small perihelion distance (Kreutz sungrazer), high dust content, not a first-time Oort Cloud visitor.

All six of these comets, and indeed all of the other comets discussed above with the exceptions of Comet Sarabat and Comet PANSTARRS C/2011 L4, either have been or will be "Comets of the Week" sometime during the course of "Ice and Stone 2020."

An appropriate question would be: when will the next "Great Comet" appear? A look back over the history of comets' appearances suggests that the average rate of "Great Comets" is about one per decade, although as in any random collection there can be wide variations in this. Nevertheless, the northern hemisphere, at least, is well overdue for one.

There are two known inbound comets at this time – both of which I mentioned in the "Comet of the Week" presentation two weeks ago – that possess at least one characteristic of a potential "Great Comet." Comet ATLAS C/2019 Y4, which passes through perihelion at the end of May, has the small perihelion distance of 0.25 AU, has apparently been around at least once before, and moreover will be exhibiting a high phase angle around the time of perihelion passage. Unfortunately, it appears to be rather faint intrinsically [– although it has brightened somewhat rapidly within the recent past –] and it is not especially well placed for observation around the time it should be brightest. We should know a lot more about this comet in about three months' time . . .



A recent image of Comet ATLAS C/2019 Y4, obtained February 15, 2020 with the Las Cumbres Observatory facility at Teide Observatory in the Canary Islands.

Meanwhile, Comet PANSTARRS C/2017 K2 possesses a high intrinsic brightness – indeed, it was located at a heliocentric distance of 16 AU when it was discovered almost three years ago. Unfortunately, it falls short when some of other factors are considered: its perihelion distance is relatively large (1.8 AU), it never comes close to Earth (being located on the far side of the sun from Earth when at perihelion), and it appears to be a first-time visitor from the Oort Cloud. Moreover, and especially frustrating for those of us in the northern hemisphere, it will be exclusively visible only from the southern hemisphere at the time it might be bright. Comet PANSTARRS passes through perihelion in late 2022 but may become bright enough to be detected visually sometime in 2020, and is a future "Comet of the Week."

In any event, I would like to see at least one more "Great Comet" before all is said and done. We'll see what happens with Comet ATLAS C/2019 Y4, and meanwhile "Ice and Stone 2020" will certainly cover other potential "Great Comets" if any should happen to come our way this year.

Ice and Stone **WORD SEARCH**

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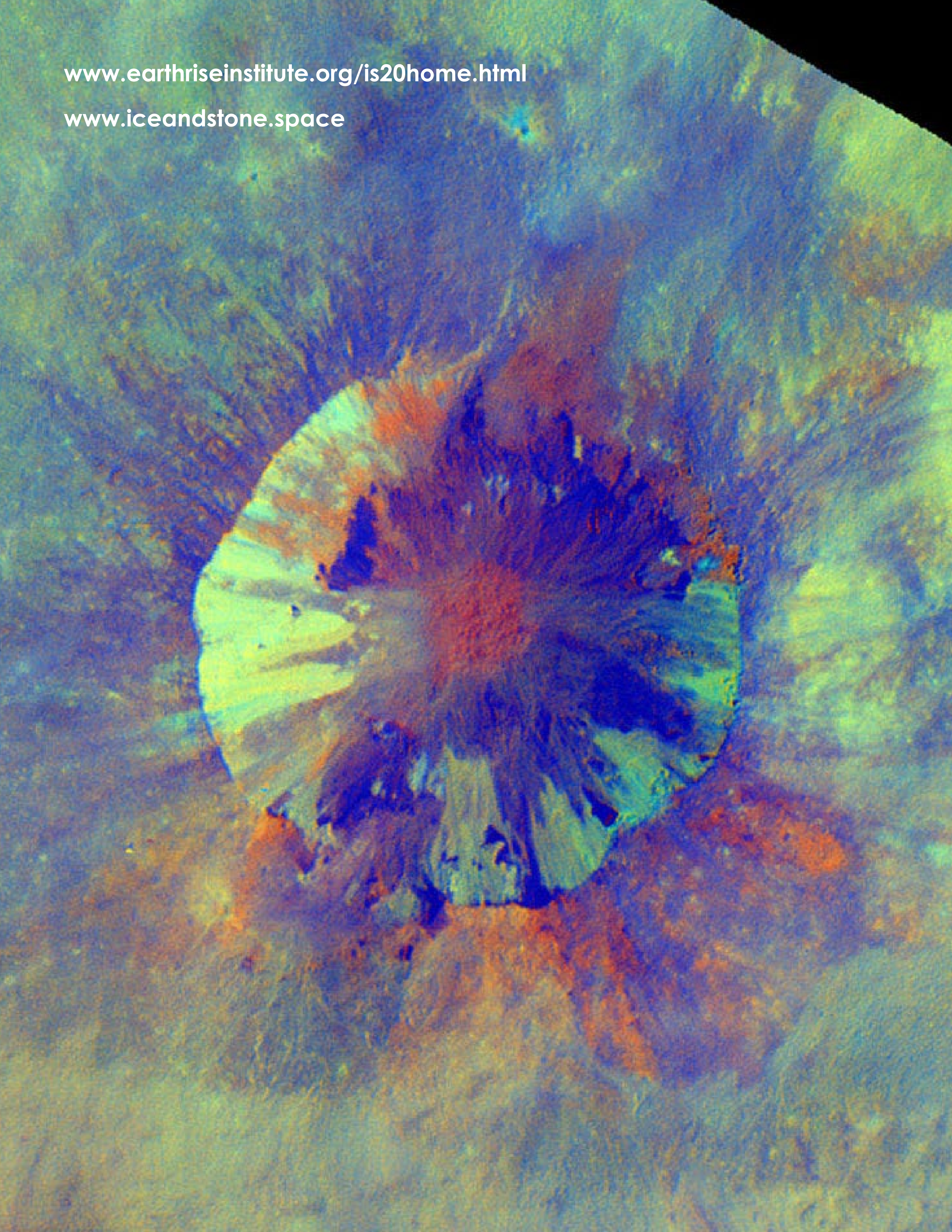
ASTEROID
ASTRONOMER
ATLAS
BENNETT
BIELA
BIG DIPPER
BRIGHTNESS
CATALINA
COMET
CORONAGRAPH
EARTH
FEDTKE
HALE-BOPP
HELIOCENTRIC
HYAKUTAKE
KONIGSBERG
LEONID
LOVEJOY
MAGNITUDE
MCNAUGHT
METEOR
OBSERVATORY
OORT CLOUD
PANSTARRS
PERIHELION
PRUSSIA
SARABAT
SHOWER
SNOWBALL
SUNGRAZER
SUNLIGHT
TAIL
TEMPEL
TEVZADZE
WEST
WHIPPLE

Image courtesy NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/JHUAPL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