ICE & STONE 2020

WEEK 32: AUGUST 2-8

Presented by The Earthrise Institute

Authored by Alan Hale

THIS WEEK IN HISTORY

AUGUST 3, 1963: U.S. Government sensors detect an airburst explosion near the Prince Edward Islands off the southern coast of South Africa. At first it was thought that this was caused by a clandestine nuclear device tested by that nation, but later study revealed that it was caused by an incoming small stony asteroid. Airburst explosions like this are discussed in a previous "Special Topics" presentation.

AUGUST 5, 1864: Italian astronomer Giovanni Donati visually observes the spectrum of Comet Tempel 1864 II, the first time that a comet's spectrum was observed. Donati detected three "bands" in the comet's spectrum, that are now known to be due to diatomic carbon.

AUGUST 5, 2126: Comet 109P/Swift-Tuttle, the parent comet of the Perseid meteors, will pass 0.153 AU from Earth, and should be a conspicuous naked-eye object. Comet Swift-Tuttle is a future "Comet of the Week."

AUGUST 6, 1835: Etienne Domouchel and Francesco de Vico at the Vatican Observatory in Rome recover Comet 1P/Halley on its return that year. This was the second predicted return of Comet Halley following the determination of its periodic nature by Edmond Halley. The comet is the subject of a previous "Special Topics" presentation, and its most recent return in 1986 is a previous "Comet of the Week."

AUGUST 6, 2014: ESA's Rosetta mission arrives at Comet 67P/Churyumov-Gerasimenko, around which it subsequently goes into orbit. Rosetta would spend the next two years performing a detailed examination of the comet before landing on the surface following the completion of its mission in September 2016. Comet Churyumov-Gerasimenko is this week's "Comet of the Week."

AUGUST 6, 4393: According to a 2017 study by astronomers Rainer Kracht and Zdenek Sekanina, Comet Hale-Bopp C/1995 O1 will next pass through perihelion at a heliocentric distance of 0.915 AU. Comet Hale-Bopp is a previous "Comet of the Week."

COVER IMAGE CREDIT:

Front and back cover: In this 30 second exposure taken with a circular fish-eye lens, a meteor streaks across the sky during the annual Perseid meteor shower as a photographer wipes moisture from the camera lenses Friday, August 12, 2016 in Spruce Knob, West Virginia.

Courtesy NASA/Bill Ingalls

AUGUST 7

AUGUST 7, 1996: A team of scientists led by NASA geologist David McKay announces that they have found "microfossils" and other evidence of possible life in the meteorite ALH 84001 which had been found to have come from Mars. The announcement set off widespread fascination and debate, and although the team's claims are not considered as being confirmed, the examination of this and other Martian meteorites continues. This topic is the subject of this week's "Special Topics" presentation.

AUGUST 7, 2006: Rob McNaught with the Siding Spring Survey in New South Wales discovers a comet, now known as Comet McNaught C/2006 P1. When Comet McNaught passed through perihelion the following January it was bright enough to see during daytime hours and it became the 21st Century's first "Great Comet." It is a previous "Comet of the Week."

AUGUST 7, 2027: The Apollo-type asteroid (137108) 1999 AN10 will pass 0.0027 AU (10 lunar distances) from Earth. With an approximate diameter of 1 km this is one of the largest asteroids to come this close to Earth within the near-term future.

AUGUST 8

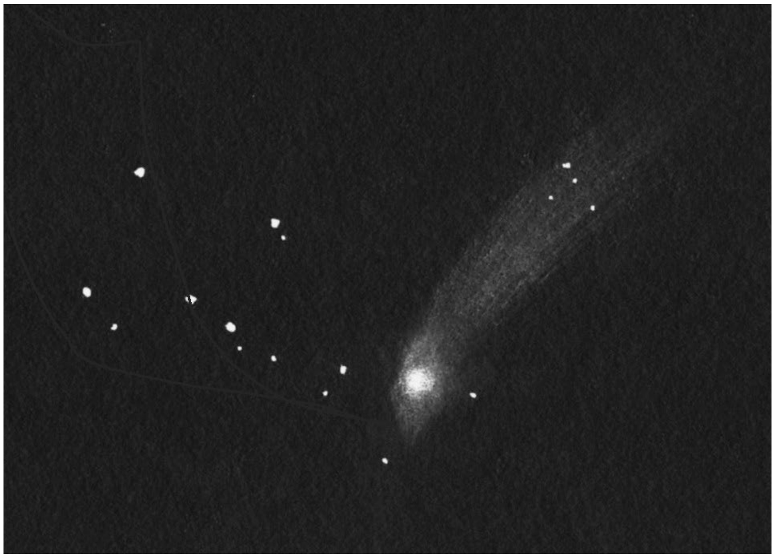
AUGUST 8, 1769: French astronomer Charles Messier discovers a comet (new style designation C/1769 P1). The comet subsequently became a conspicuous naked-eye object and was the brightest comet that Messier discovered. It is a future "Comet of the Week."

AUGUST 8, 1991: Radar experiments with the 70-meter antenna at Goldstone, California and the Very Large Array in New Mexico carried out by a team of astronomers led by Martin Slade provide evidence for the existence of water ice in permanently-shadowed craters near Mercury's north pole. This ice, the presence of which has since been confirmed by NASA's MESSENGER spacecraft, and how it got there is discussed in a future "Special Topics" presentation.

AUGUST 8, 2013: Scottish scientist Daniel Garcia Yarnoz and his colleagues publish a list of the top dozen "easily retrievable objects" among the small near-Earth asteroids known at that time. This list was intended to be a first attempt at identifying objects that could be brought back to Earth's vicinity for resource extraction purposes, a topic which is the subject of a previous "Special Topics" presentation.

COMET OF THE WEEK: 67P/CHURYUMOV-GERASIMENKO

Perihelion: 2015 August 13.08, q = 1.243 AU

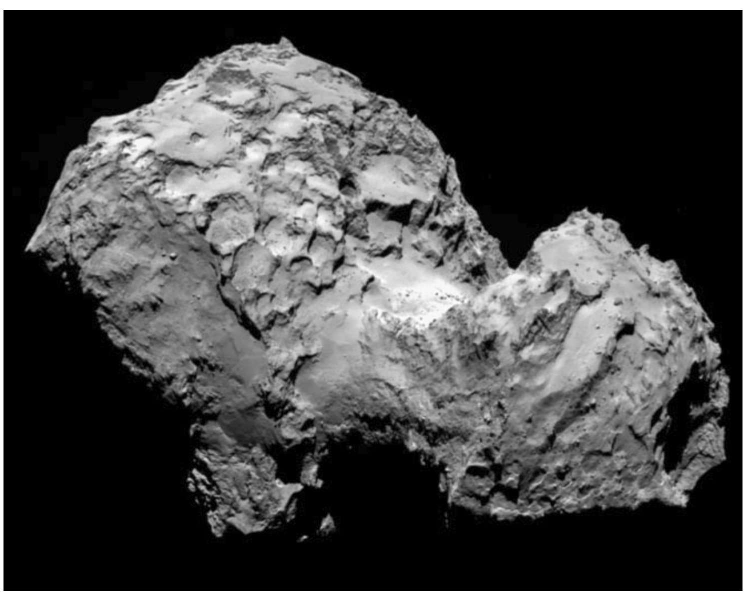


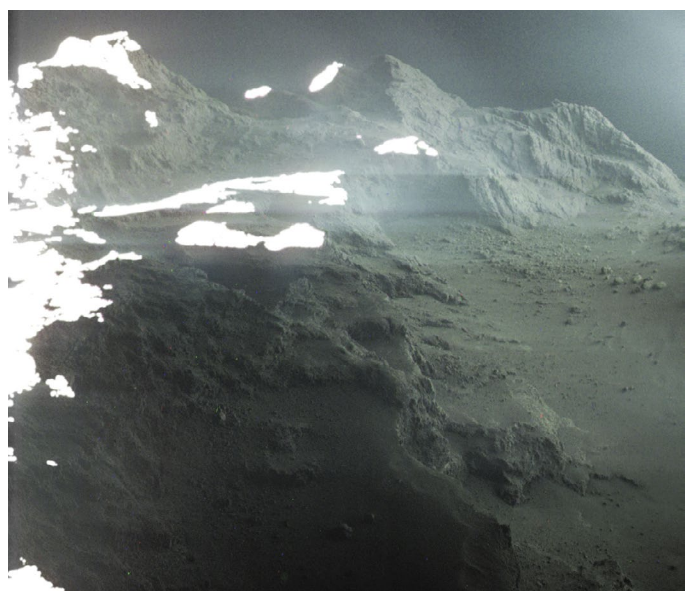
A sketch I made of Comet 67P's visual appearance through a 20-cm telescope on December 24, 1982.

There have been a handful of occasions throughout recent history when someone has discovered a comet while looking for, or examining, another one. Such an incident happened in late 1969 in the former Soviet Union, when on September 11 Svetlana Gerasimenko with the Alma Ata Observatory (in what is present-day Kazakhstan) took photographs of Comet 32P/Comas Sola. Klim Churyumov, then with the Kiev Observatory, performed the astrometric measurements of what he believed was that comet, but a month later realized that the positions were far off. Upon re-examining the photographs he found that he had in fact measured a previously-unknown comet that was some two magnitudes brighter than Comet Comas Sola (that was also on the photographs).

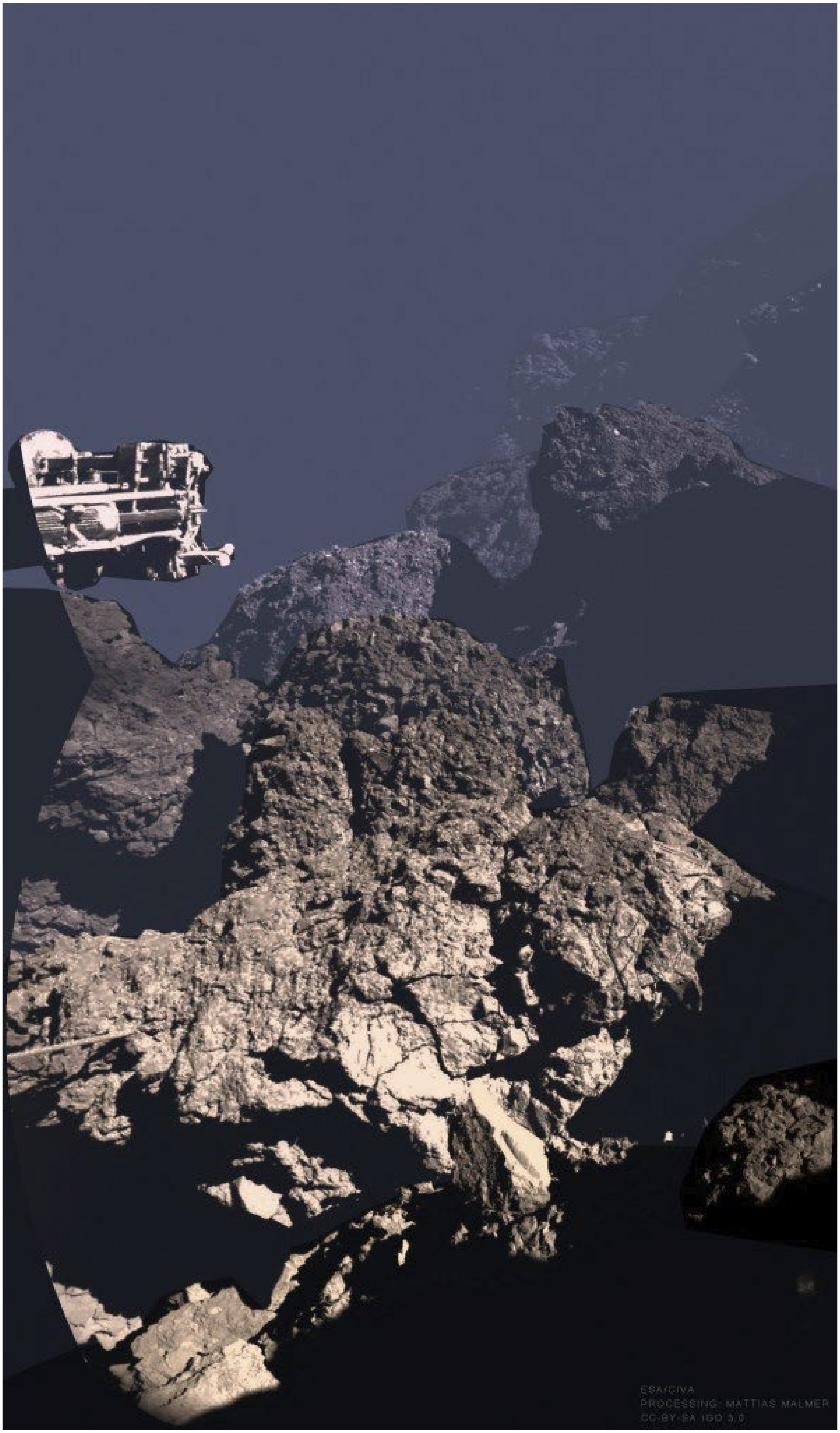
The newly-discovered Comet Churyumov-Gerasimenko was found to have an approximate orbital period of 6.6 years. It has been recovered on every return since then, and during the 1982 return, which took place under very favorable viewing geometry, it reached 9th magnitude and I was able to detect it with binoculars. It also exhibited a distinct dust tail which on one occasion I measured as being 20 arcminutes long visually.

Comet 67P achieved fame in the mid-2000s when it was selected as the destination for ESA's ambitious Rosetta mission. Rosetta had originally been scheduled for launch in January 2003 with its destination being Comet 46P/Wirtanen, however a failure of the Ariane 5 launch rocket a month earlier

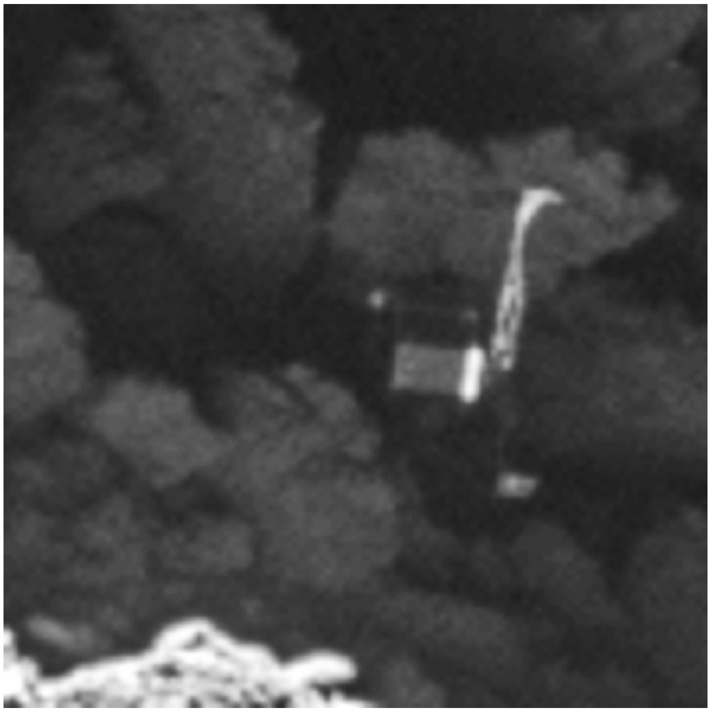




Left: The inactive nucleus of Comet 67P, showing the two hemispheres of its "contact binary" structure, as imaged by Rosetta on August 3, 2014. Courtesy ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA. Right: Colorized and slightly processed image of Comet 67P's surface, taken by Rosetta on September 22, 2014. Within a year part of the cliff on the lower left had collapsed due to the comet's activity. Courtesy ESA/Rosetta/MPS for OSIRIS Team/ MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA/Jacint Roger.



Colorized and slightly processed image taken by Philae's camera of its landing site. One of Philae's landing legs is at upper left. Original image courtesy ESA/ Rosetta/ Philae/CIVA; processing courtesy Mattias Malmer of Stockholm, Sweden.



Philae at its landing site, as imaged by Rosetta on September 2, 2016. Courtesy ESA/Rosetta/MPS for OSIRIS Team.

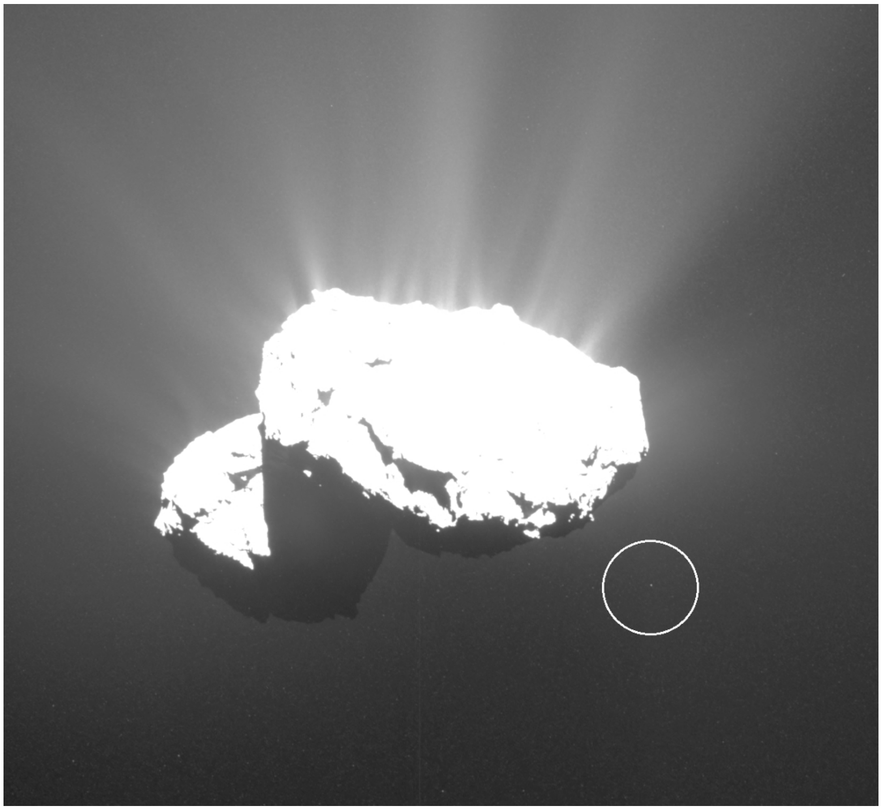
grounded all flights of that vehicle until the necessary failure analysis could be conducted. Comet 67P was accordingly chosen as the new destination.

Rosetta was successfully launched from Kourou, French Guiana on March 2, 2004. Over the next 5½ years it performed three gravity-assist flybys of Earth as well as a very close gravity-assist flyby of Mars, and – as discussed in a previous "Special Topics" presentation – it also performed flybys of the main-belt asteroid (2867) Steins in September 2008 and the larger main-belt asteroid (21) Lutetia in July 2010. Not too long after the Lutetia encounter Rosetta was placed in a state of hibernation, from which it was awoken in January 2014. From there it made its final approach to Comet 67P, arriving there on August 6 of that year, and after various maneuvers it successfully entered orbit around the comet's nucleus a month later.

The approach photographs showed that the comet's nucleus is made up of two discrete hemispheres, one distinctly larger than the other, making it a "contact binary" similar to several of the near-Earth asteroids that have been successfully radar-imaged (and also the Kuiper Belt object (486958) Arrokoth that was visited by the New Horizons mission at the beginning of 2019). The evidence that has been collected suggests that the two hemispheres were at one time two separate objects that collided and stuck together a long time ago, and based upon the various other objects that exhibit such a structure it would appear that this is a relatively common occurrence amongst the "small bodies" of our solar system.

At the time of Rosetta's arrival Comet 67P was a full year away from perihelion passage, and the overall rationale for the mission was to examine the comet as it approached perihelion and became active, and then as it began to shut down as it receded from perihelion. With an onboard complement of eleven scientific instruments Rosetta was able to conduct numerous scientific studies throughout that time, and among its findings were numerous organic compounds, including four for the first time (one of these being acetone), a deuterium-to-hydrogen ratio in its water that is three times higher than that in Earth's seawater – the significance of these findings being part of the subject of a future "Special Topics" presentation – large amounts of free oxygen (which was quite unexpected), a lack of a magnetic field, and the appearances of numerous "sinkholes" and the crumbling of cliffs as the comet's activity proceeded.

Rosetta also carried a separate probe, Philae, that was designed to soft-land upon the comet's nucleus.



The active nucleus of Comet 67P on October 21, 2015. The "Churyumoon" is circled. Courtesy ESA/Rosetta/MPS/OSIRIS/UPD/LAM/IAA/SSO/INTA/UMP/DASP/ IDA/Jacint Roger.

Comet 67P as imaged on June 24, 2015, from Siding Spring Observatory in New South Wales. Courtesy Jose Chambo.

Rosetta released Philae on November 12, 2014, for a seven-hour descent to the comet's surface, but unfortunately the planned anchoring system failed and Philae bounced twice before coming to rest, apparently on its side in a hole next to some high cliffs. It was nevertheless able to carry out various scientific observations during the 60 hours before its battery power ran out, and while the cliffs were apparently made of a rather porous material, Philae's drilling "hammer" broke after a few minutes, indicating that the ground underneath it was very hard, either rock or solid ice. After its batteries ran out contact with Philae was lost; meanwhile, there was hope that a better sun angle later in the mission might allow for the batteries to be recharged to an extent, and in fact contact was briefly restored on a couple of occasions in June and July 2015 but unfortunately not long enough for any significant data transmission.

Rosetta's mission was formally scheduled to end at the end of 2015, however before that time the mission was extended until the end of September 2016, i.e., a full year after the comet's perihelion passage and two full years after the spacecraft's arrival. As that time approached Rosetta was placed into progressively lower orbits, and on September 2 it successfully photographed Philae, on its side and wedged against a large overhanging cliff. On September 30 Rosetta touched down upon the comet's surface, and contact was terminated.

The large collection of data collected by Rosetta during the two years it spent orbiting Comet Churyumov-Gerasimenko is still being analyzed, and will continue to be for some time yet to come. Just last year, for example, a Spanish amateur astronomer, Jacint Roger, was examining Rosetta images when he found a four-meter-wide moon in images that had been taken on October 21, 2015. This "Churyumoon," as it was dubbed, was not a permanent feature, but did orbit the nucleus at a distance of 2 to 3 km for the next two days before disappearing.

The viewing geometry during Comet 67P's 2015 return to perihelion was not especially favorable, with the comet for the most part remaining at a moderately low elongation in the morning sky and reaching a peak brightness of about 12th magnitude. Meanwhile, although it won't have the fanfare that accompanied this recent return, the comet's next return, in 2021, is a very favorable one, similar to that of 1982. It passes through perihelion on November 2 and is closest to Earth (0.42 AU) less than two weeks later, and once again should reach a peak brightness around 9th magnitude.

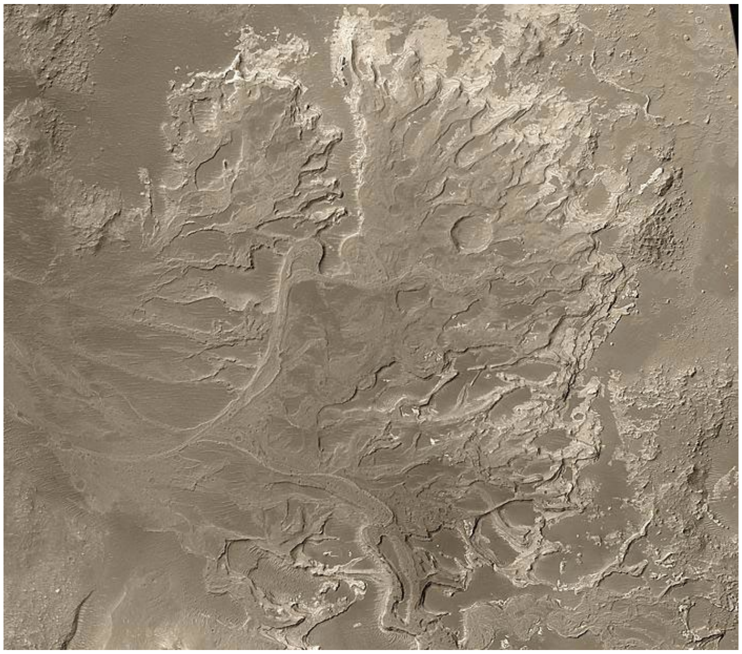
SPECIAL TOPIC: LIFE IN MARTIAN METEORITES?

On-the-ground image demonstrating the existence of Martian surface water in the past. In this photo, the Curiosity rover captured sedimentary plate structures in Gale Crater. Courtesy NASA.

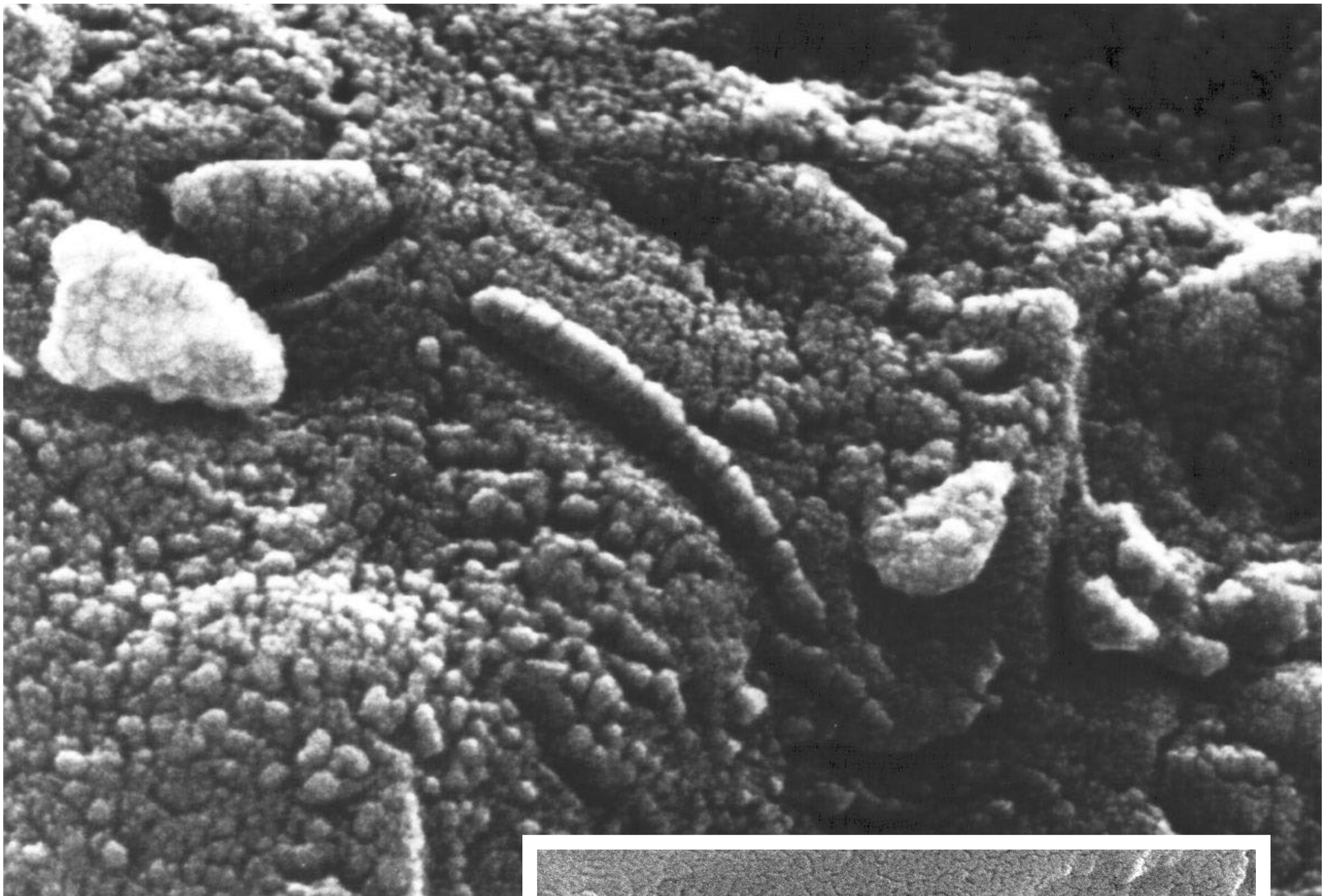
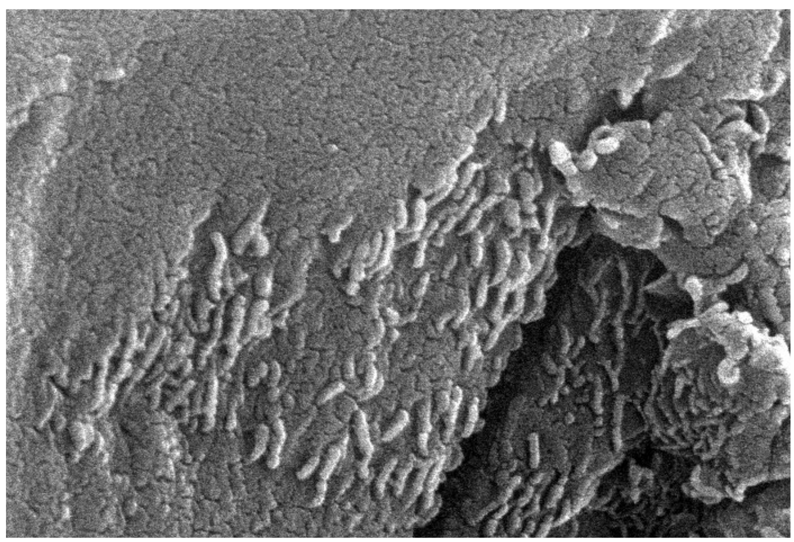
The question as to whether or not we are alone in the universe has fascinated humanity throughout most of its history. In addition to driving many of our mythologies and stories, it has also motivated many of us, myself included, to pursue sciences like astronomy in the first place. The unambiguous discovery that life has arisen elsewhere in the universe independently of Earth would, without question, be one of the greatest discoveries in the entire history of science.

The planet Mars, in particular, has long been a focus in the quest for extraterrestrial life. Potential Martian life has figured prominently in much of our social consciousness, for example, the late 19th Century American amateur astronomer Percival Lowell (whose estate would eventually fund the discovery of Pluto) popularized the idea that Mars was peopled by a dying civilization that built a planet-wide network of "canals" that distributed a declining water supply. Much of our science fiction, especially earlier stories, featured Martian life in some form or other, sometimes malevolent as in the classic H.G. Wells novel "The War of the Worlds," and sometimes more benign.

The more optimistic views of a thriving Martian ecosphere were dashed rather considerably by the flyby of NASA's Mariner 4 mission in July 1965, which among other things revealed a stark cratered landscape, although more recent missions have shown that the overall picture is far more complex than that. Various experiments conducted on Martian soil by the twin Viking landers in 1976 did not reveal any convincing evidence of biological activity, however the Viking orbiters, and various missions



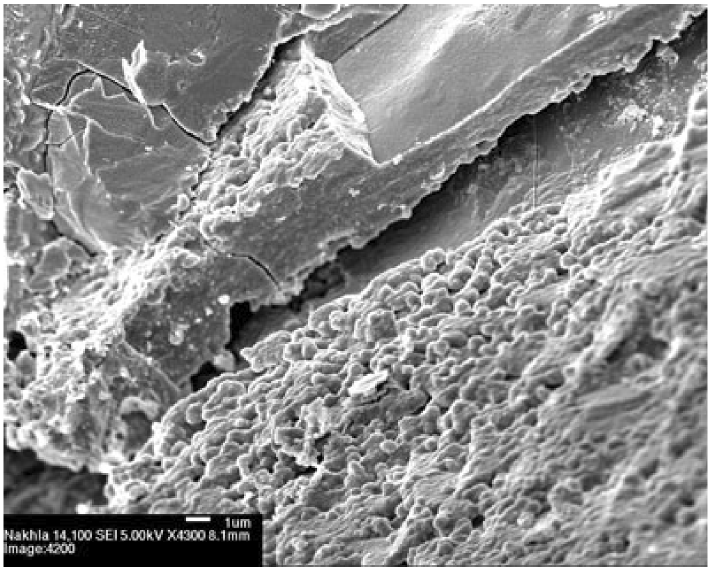
Another spacecraft image demonstrating the existence of Martian surface water in the past. This image from the Mars Orbiter Camera aboard NASA's Mars Global Surveyor reveals water-eroded structures in an ancient delta in Eberswalde Crater. Courtesy NASA.

Scanning electron microscope images of possible "microfossils" in Martian meteorite ALH 84001. Both images courtesy NASA.

since then, have revealed that the Martian surface at one time contained significant amounts of water. Findings by the rovers Spirit, Opportunity, and Curiosity over the past decade and a half have confirmed that, early in its history, Mars had numerous lakes and seas on its surface. Much of that water has either evaporated into space and/or is now below the surface in frozen form, and indeed there is some spacecraft evidence of the existence of subsurface aquifers. Since life – at least, "life as we know it" – needs water to survive, it is certainly conceivable that some forms of life existed on Mars during that watery era billions of years ago but is no longer present. Even if, as would seem likely, that life never evolved beyond microscopic size, the verification that such life indeed arose and existed would still be of monumental scientific importance.

The first strong pieces of evidence that Martian life had indeed existed at one point came from what at face value might seem an unlikely source: Earth itself. Over the age of the solar system numerous large objects would strike Mars from time to time, some with enough force to eject surface fragments off Mars entirely into interplanetary space – this being due both to Mars' relatively thin atmosphere as well as its lower surface gravity than Earth's. These fragments would subsequently orbit the sun as small asteroids until at some point – millions of years in the future – some of them would occasionally encounter Earth and fall to the surface as meteorites. Such an object could be identified due to the fact that the isotopic composition of its materials would match that measured in the Martian soil by surface probes (beginning with the Viking landers in 1976) and while



Scanning electron microscope image of a possible bacterial "mat" within the Nakhla meteorite. Courtesy NASA.

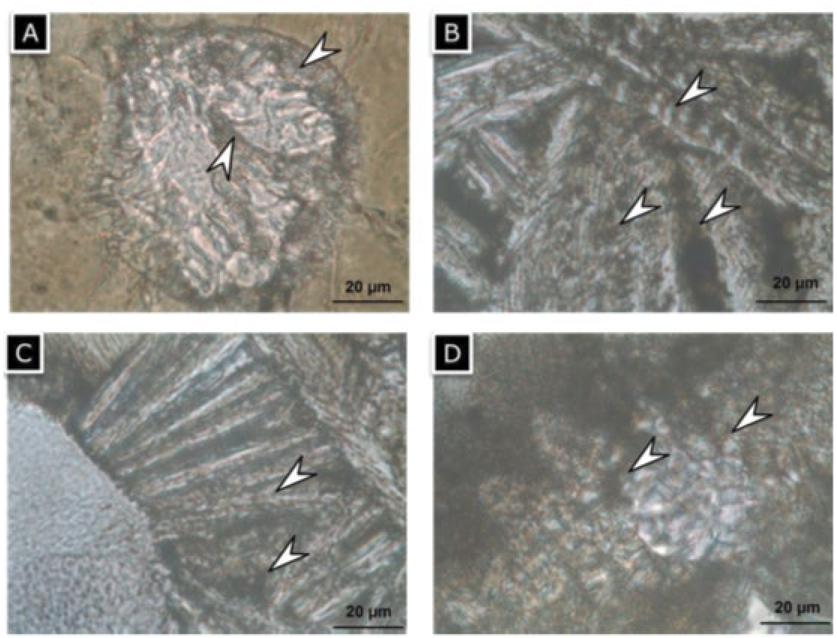
this place of origin could not, for obvious reasons, be positively identified until after such probes had been to Mars, even prior to that it was obvious that the composition of these meteorites was different from that of more "typical" meteorites. The earliest "Martian meteorite" to be collected fell near the town of Chassigny in northeastern France on October 3, 1815, and as of now slightly over 220 meteorites have been identified as having come from Mars.

On August 7, 1996, a team of scientists led by David McKay of NASA's Johnson Space Center announced that they had detected various signs of evidence of prehistoric Martian life in the Martian meteorite ALH 84001, a 1.9-kg achondrite meteorite collected in the Allan Hills region of Antarctica in December 1984. Among the evidence cited by McKay's team was the existence of apparent "microfossils" of bacterial organisms a few tens of nanometers in size, similar to – albeit much smaller than – terrestrial bacteria (although perhaps not significantly smaller than bacteria that existed on Earth during its early natural history). Among other forms of evidence, the team cited the existence of several specimens of organic molecules known as "polycyclic aromatic hydrocarbons," or PAHs, the production of which is usually associated with biological activity. While each of the various forms of evidence could be produced by non-biological means, McKay's team argued that the totality of all the evidence combined pointed to a biological origin.

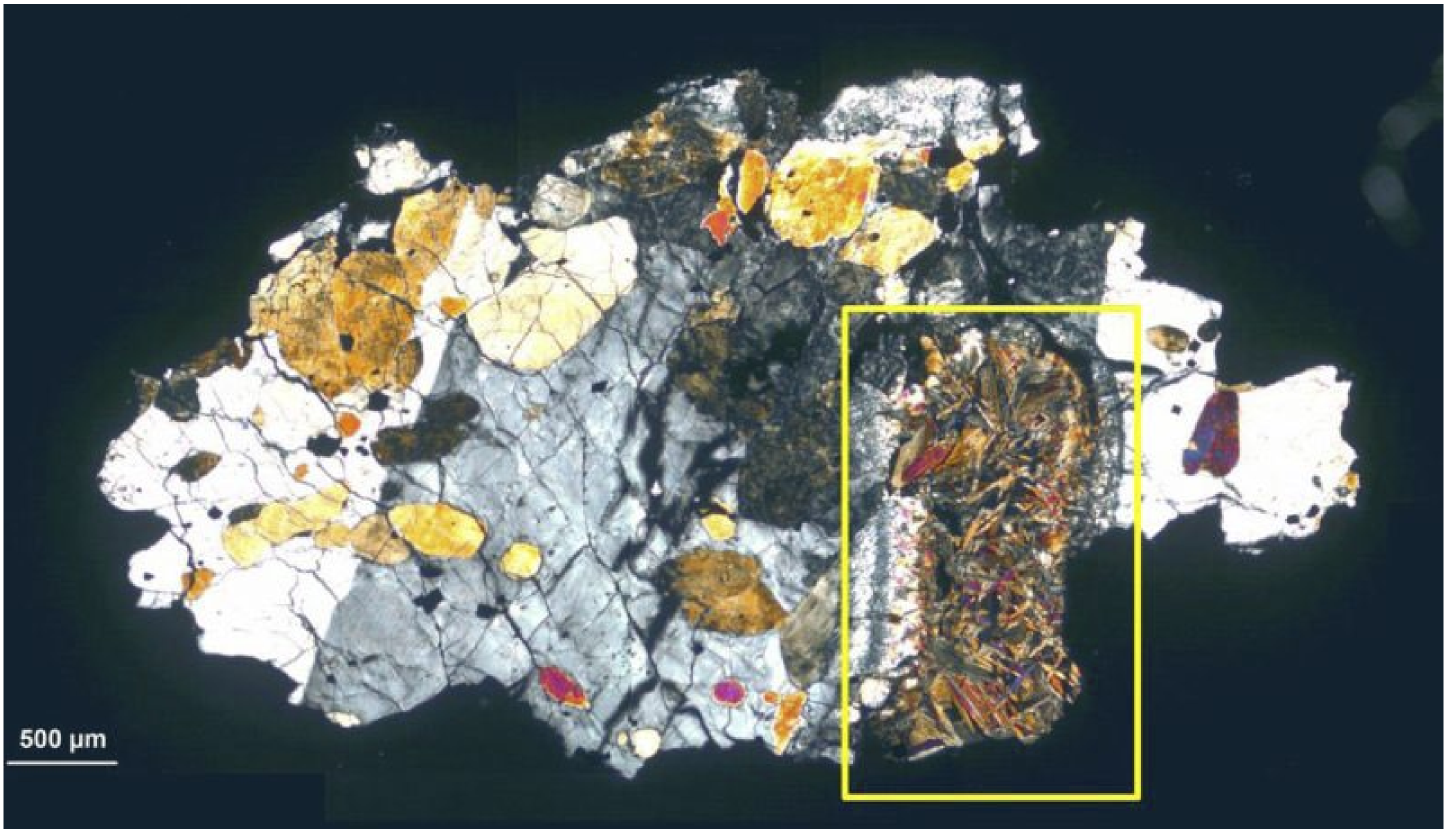
The specific origin of the meteorite ALH 84001 itself figures into the overall story. Overall it has been dated as being somewhat over 4 billion years old – in other words, shortly after the formation of Mars itself – although the specific sections of ALH 84001 that contain the putative biological evidence are somewhat younger, about 3.6 billion years old – roughly the same era during which significant water was present on Mars' surface (and during which life conceivably could have existed). The impact that blasted ALH 84001 from the Martian surface seems to have occurred around 17 million years ago, and it fell to Antarctica approximately 13,000 years ago. Although there is probably no way this can be confirmed at present, there is evidence to suggest that it might have come from the vicinity of Eos Chasma, the southern portion of the Valles Marineris (Mars' "Grand Canyon").

It essentially goes without saying that the announcement by McKay's team generated a large amount of discussion, debate, and controversy. During the years since then several scientists have pointed out that the "microfossils," while intriguing, are not necessarily proof of biological structures, and that similar structures can be produced by other natural, non-biological means. Similar arguments can also be made about the various other forms of evidence that McKay's team cited, such as the presence of PAHs. The overall consensus has been that the case for proving a biological presence in ALH 84001 has not been met.

In 2010 McKay and other team members announced that continued analysis of ALH 84001 and two additional Martian meteorites – one of which is the famous Nakhla meteorite that fell on Egypt in 1911 – with modern instruments not available in the mid-1990s has revealed more compelling evidence for



Four images of suspected signs of biological activity within ALH 77005. The scales are in the lower right corner of each image. All images are from Gyollai et al. (2019).



Thin slice of the Martian meteorite ALH 77005. The region within the yellow rectangle is where evidence for biological activity was found. Image is from Gyollai et al. (2019).

a biological presence in these meteorites, including the presence of "mat"-like structures similar to those that were produced by ancient bacterial life forms on Earth. Although the case for Martian biology in these meteorites could still not be considered proven, it could nevertheless be considered as being stronger, and even though McKay passed away in 2013, analysis by other team members and other scientists is ongoing.

A new contribution to this overall discussion came out last year, when a team of Hungarian scientists led by Ildiko Gyollai at the HAS Research Centre for Astronomy and Earth Sciences in Budapest announced that their examination of another Martian meteorite retrieved from Allan Hills – ALH 77005, retrieved in 1977 – shows that it contains new evidence of biological activity, including filamentary structures indicative of iron-oxidizing bacteria. Some of the structures appear to be due to fossilized bacteria itself, while others appear to be chemical alterations to the surrounding rock produced by the bacteria.

As intriguing as all of this evidence might be, it still cannot be considered conclusive at this time. When it comes to something as monumental as the existence of indigenous life beyond Earth, the famous dictum attributed to the late planetary scientist Carl Sagan, i.e., "extraordinary claims require extraordinary evidence," holds. It should also be kept in mind that in such instances, the burden of proof is on the positive, i.e., it must be proven by direct evidence, not just by eliminating other potential explanations and then asking "what else can it be?" It may be that, short of actual living organisms, evidence strictly from meteorites may not be enough to meet this burden of proof, and direct analysis of Martian soil and rocks will be necessary to establish the presence of Martian life, if indeed it exists, or has existed in the past. If its mission is successful, NASA's just-launched Perseverance rover may well be an important step in this process. (Meanwhile, it perhaps should be stated that all of the meteorites that have been studied in this endeavor have been thoroughly examined to the point where the possibility of contamination by terrestrial life forms has been eliminated.)

Regardless of the final disposition of the existence, or non-existence, of biological activity in ALH 84001 and other Martian meteorites, the excitement and resultant discussion generated a new wave of interest in the possibility of Martian (and overall extraterrestrial) life. Indeed, in 1998 NASA established the NASA Astrobiology Institute – which has now been transformed into a more globally-focused collaborative effort – as a direct result of the interest, both scientific and popular, generated by the McKay team's announcement. Perhaps some "Ice and Stone 2020" participants may one day play a role in furthering this discussion and establishing once and for all whether or not we are alone in the universe.

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PDF booklet prepared by RocketSTEM