ICE & STONE 2020

WEEK 43: OCTOBER 18-24

Presented by The Earthrise Institute

43

Authored by Alan Hale

THIS WEEK IN HISTORY

OCTOBER 18 | 19 | 20 | 21 | 22 | 23 | 24

OCTOBER 18, 1977: Charles Kowal discovers the first-known centaur, (2060) Chiron, with the 1.2-meter Schmidt telescope at Palomar Observatory in California. Centaurs are the subject of a previous "Special Topics" presentation.

OCTOBER 18, 1989: NASA's Galileo mission is deployed from the Space Shuttle Atlantis, with its final destination being Jupiter. While en route to Jupiter Galileo made the first spacecraft flybys of asteroids, (951) Gaspra in 1991 and (243) Ida in 1993 – discovering the moon Dactyl orbiting around Ida in the process – and also observed some of the impacts of Comet Shoemaker-Levy 9 into Jupiter in July 1994.

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OCTOBER 19, 2011: A team led by Carey Lisse of John Hopkins University's Applied Physics Laboratory announces that they have detected evidence of cometary impacts into forming planets around the star Eta Corvi in infrared data taken by the Spitzer Space Telescope. This is analogous to the period of Late Heavy Bombardment in our solar system – discussed in a future "Special Topics" presentation – and the Eta Corvi results are discussed in a previous "Special Topics" presentation on "exocomets."

OCTOBER 19, 2014: Comet Siding Spring C/2013 A1 passes just 0.00094 AU – one-third of a lunar distance – from Mars, and is observed by spacecraft in Mars orbit and on the surface. It is this week's "Comet of the Week."

OCTOBER 19, 2017: The Pan-STARRS survey program in Hawaii discovers the object now designated as 1I/'Oumuamua, the first-known object from interstellar space to pass through our solar system. 'Oumuamua is the subject of this week's "Special Topics" presentation.

OCTOBER 19, 2020: The Amor-type asteroid (159402) 1999 AP10 will pass 0.081 AU from Earth. It is currently near magnitude 12.5 and is traveling northward through the constellations of Lacerta, Cygnus, and Cepheus; on November 3 it passes within 1½ degrees of the North Celestial Pole but will have faded to magnitude 13.5 by then.

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OCTOBER 20, 2010: Comet 103P/Hartley 2 passes 0.121 AU from Earth, reaching a peak brightness of 5th magnitude. Two weeks later the comet was encountered by NASA's EPOXI mission, and this event is described in a previous "Special Topics" presentation.

OCTOBER 20, 2020: NASA's OSIRIS-REx mission is expected to extract soil samples from the "Nightingale" site on the near-Earth asteroid (101955) Bennu, for eventual return to Earth in 2023. The OSIRIS-REx mission is discussed in a future "Special Topics" presentation.

OCTOBER 20, 2020: The recently-discovered Comet NEOWISE C/2020 P1 will pass through perihelion at a heliocentric distance of 0.342 AU. If it survives its perihelion passage it should become visible in the northern hemisphere's morning sky late this month, possibly bright enough to detect in binoculars. Information about Comet NEOWISE can be found at the Comet Resource Center.

OCTOBER 20, 2020: The main-belt asteroid (71733) 2000 JQ47 will occult the 7th-magnitude star HD 756 in Andromeda. The predicted path of the occultation crosses northwestern Ukraine, far southwestern Belarus, northeastern Poland, northern Denmark, northern Scotland, far southeastern Canada including Newfoundland and New Brunswick, the eastern U.S. from Maine to Louisiana, and central Mexico.

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OCTOBER 21, 1965: Comet Ikeya-Seki 1965f, the brightest comet to appear during the 20th Century, passes through perihelion at a heliocentric distance of 0.008 AU. Comet Ikeya-Seki was a Kreutz sungrazer – the subject of next week's "Special Topics" presentation – and it is also next week's "Comet of the Week."

OCTOBER 21, 2003: A team led by Michael Brown of CalTech obtains the discovery images of the world now known as (136199) Eris with the 1.2-meter Schmidt telescope at Palomar Observatory in California, although the images were not recognized at first and the discovery was not announced until July 2005. Eris turns out to be just smaller than Pluto in size although more massive than Pluto, and was responsible for forcing the issue of what is and what is not a "planet;" it is now listed as a "dwarf planet." The Kuiper Belt, within which Eris orbits, and the definition of "planet," are discussed in previous "Special Topics" presentations.

OCTOBER 21, 2015: Cameras aboard ESA's Rosetta mission detect a tiny moon orbiting the nucleus of Comet 67P/Churyumov-Gerasimenko. Dubbed "Churyumoon," this object orbited the nucleus for two days before disappearing. Comet 67P is a previous "Comet of the Week."

OCTOBER 21, 2020: The Orionid meteor shower, which is associated with Comet 1P/Halley, will be at its peak. The Orionids normally exhibit a peak rate of 20 to 25 meteors per hour. The moon will be a few days past its "new moon" phase and thus viewing conditions for the Orionids are good this year.

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OCTOBER 22, 2023: Comet 2P/Encke will pass through perihelion at a heliocentric distance of 0.340 AU. This year's return of 2P/Encke, during which it was visible from the southern hemisphere after perihelion, is a previous "Comet of the Week;" in 2023 the comet will be moderately well-placed from the northern hemisphere and should reach 7th magnitude in early October before disappearing into morning twilight.

OCTOBER 22, 2183: Comet 9P/Tempel 1 will pass just 0.02 AU from Mars. This is the only comet to have been encountered by spacecraft on two different returns and it is a previous "Comet of the Week."

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OCTOBER 23, 1924: Walter Baade at Bergedorf Observatory in Germany discovers the asteroid now known as (1036) Ganymed. Ganymed is an Amor-type asteroid and, with an average diameter of approximately 35 km, is the largest near-Earth asteroid. It and other near-Earth asteroids are discussed in the Week 2 "Special Topics" presentation.

OCTOBER 23, 1992: A team led by Walter Slade of NASA's Jet Propulsion Laboratory announces that, in radar data taken with NASA's tracking antenna at Goldstone, California and with the Very Large Array radio telescope in New Mexico, they have detected evidence of water ice near Mercury's north pole. The presence of ice near Mercury's poles would be confirmed two decades later by NASA's MESSENGER spacecraft, and its existence, and the significance of its presence, are discussed in a previous "Special Topics" presentation.

18 19 20 21 22 23 OCTOBER 24

OCTOBER 24, 1990: Comet Levy 1990c passes through perihelion at a heliocentric distance of 0.939 AU. Comet Levy was the first comet to be observed by the Hubble Space Telescope, and is a previous "Comet of the Week."

OCTOBER 24, 1998: NASA's Deep Space 1 spacecraft, a technology test bed mission, is launched from Cape Canaveral, Florida. Deep Space 1 encountered the Mars-crossing asteroid (9969) Braille in July 1999 and Comet 19P/Borrelly in September 2001, and is discussed in a previous "Special Topics" presentation.

OCTOBER 24, 2007: Comet 17P/Holmes undergoes an outburst of almost 15 magnitudes, a brightness increase by a factor of 600,000 – the largest cometary outburst ever recorded. It is a future "Comet of the Week."

OCTOBER 24, 2020: The main-belt asteroid (1171) Rusthawelia will occult the 6th-magnitude star 29 Ceti. The predicted path of the occultation crosses central and eastern Russia (including Volgograd), far northern Kazakhstan, the Crimean peninsula, (including Sevastopol), eastern and southern Bulgaria, northern Greece (including Thessaloniki), southern Albania, far southwestern Italy including most of Sicily, northern Tunisia, northern Algeria, and eastern and southern Morocco.

Ice and Stone **WORD SEARCH**

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E X D S I A I B Q B Y C E N T A U R A C
S G E U T P N D X A C E L E S T I A L U
C O M R R W S E I N T E R S T E L L A R
O O H V A O H O T N V C E R O B U P U P
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ASTEROID
BRIGHTNESS
CATALINA
CELESTIAL
CENTAUR
COMET
ELLIPSOID
ENCOUNTER
EPOXI
ERIS
GALILEO
INTERSTELLAR
KUIPER
MAGNITUDE
OBSERVATORY
OORTCLOUD
OPPORTUNITY
ORBIT
ORIONID
OUMUAMUA
OUTBURST
PALOMAR
PERIHELION
PLANETESIMALS
POROUS
SIDING SPRING
SPITZER
SURVEY
TELESCOPE
TRAJECTORY

COMET OF THE WEEK: SIDING SPRING C/2013 A1

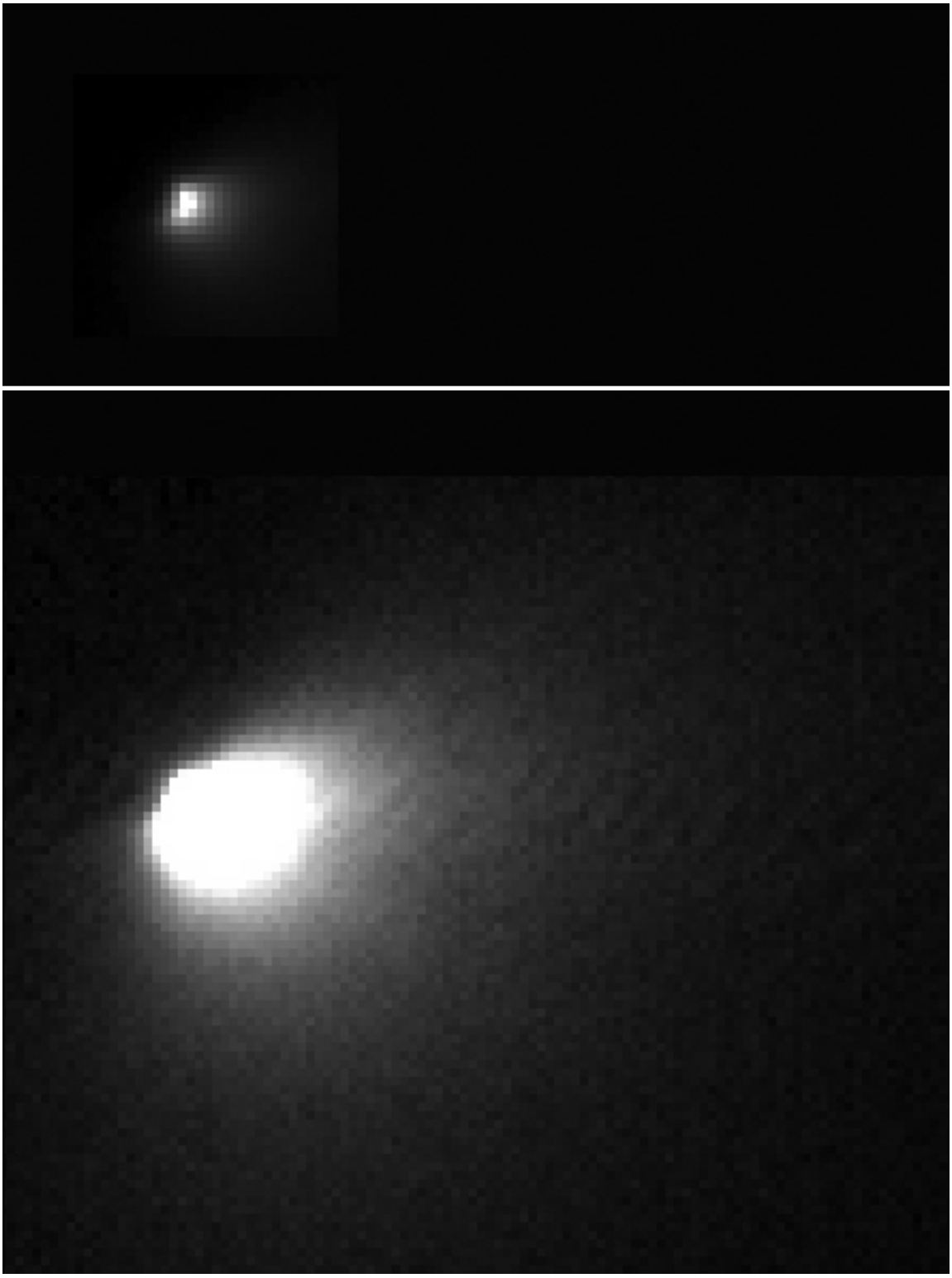
Perihelion: 2014 October 25.30, q = 1.399 AU

Comet Siding Spring on July 6, 2014, as imaged from Namibia. Courtesy Gerald Rhemann from Austria.

Of the various comprehensive survey programs that have been operational since the first such programs commenced in the late 1990s, only one has been based in the southern hemisphere: the Siding Spring Survey, based at its namesake observatory in New South Wales and which operated with funding from NASA under the management of the Catalina Sky Survey program based in Arizona. The Siding Spring Survey became operational in 2004 and ran until its funding was terminated in mid-2013, and during that time managed to gather a respectable collection of discoveries of comets and near-Earth asteroids, perhaps the most memorable discovery being Comet McNaught C/2006 P1, which became a "Great Comet" in early 2007 and which is a previous "Comet of the Week."

One of the most important Siding Spring discoveries came just a few months before the program shut down, when on January 3, 2013, Rob McNaught discovered a dim object of about magnitude 18.5. Poor atmospheric conditions and a collimation problem with the telescope prevented its cometary nature from being determined right away – hence the name "Siding Spring" – but observations soon showed that McNaught's object was a condensed comet over 21½ months away from perihelion passage and located at a heliocentric distance of 7.20 AU.

Orbital calculations soon began to show that in October 2014 – just a few days before perihelion passage – Comet Siding Spring would be passing extremely close to Mars. Indeed – and in the



Two images of Comet Siding Spring taken on October 19, 2014, with the HIRISE camera aboard NASA's Mars Reconnaissance Orbiter. The top image is a short exposure showing the bare nucleus and its immediate surroundings; the bottom image is a longer exposure showing the inner coma. Courtesy NASA.

process described within a previous "Special Topics" presentation – Mars remained within the comet's "error ellipsoid" for a while, but calculations eventually established that at the time of closest approach on October 19 the comet's "miss distance" would be a very small 0.00094 AU – 141,000 km, just barely over 1/3 of the Earth-moon separation. I will confess that, at least among some of us involved in cometary astronomy (as well as within the planetary defense community) there was some disappointment that there wouldn't be an actual impact; in addition to being a truly spectacular event in and of itself, the scientific windfall from an impact (which, since the comet's orbit is retrograde, would have occurred at a relative velocity of 56 km/sec) would have been enormous. Still, with an international armada of spacecraft both in orbit around Mars and upon Mars' surface, this provided an unprecedented opportunity to obtain close-up observations of a long-period comet from the Oort Cloud.

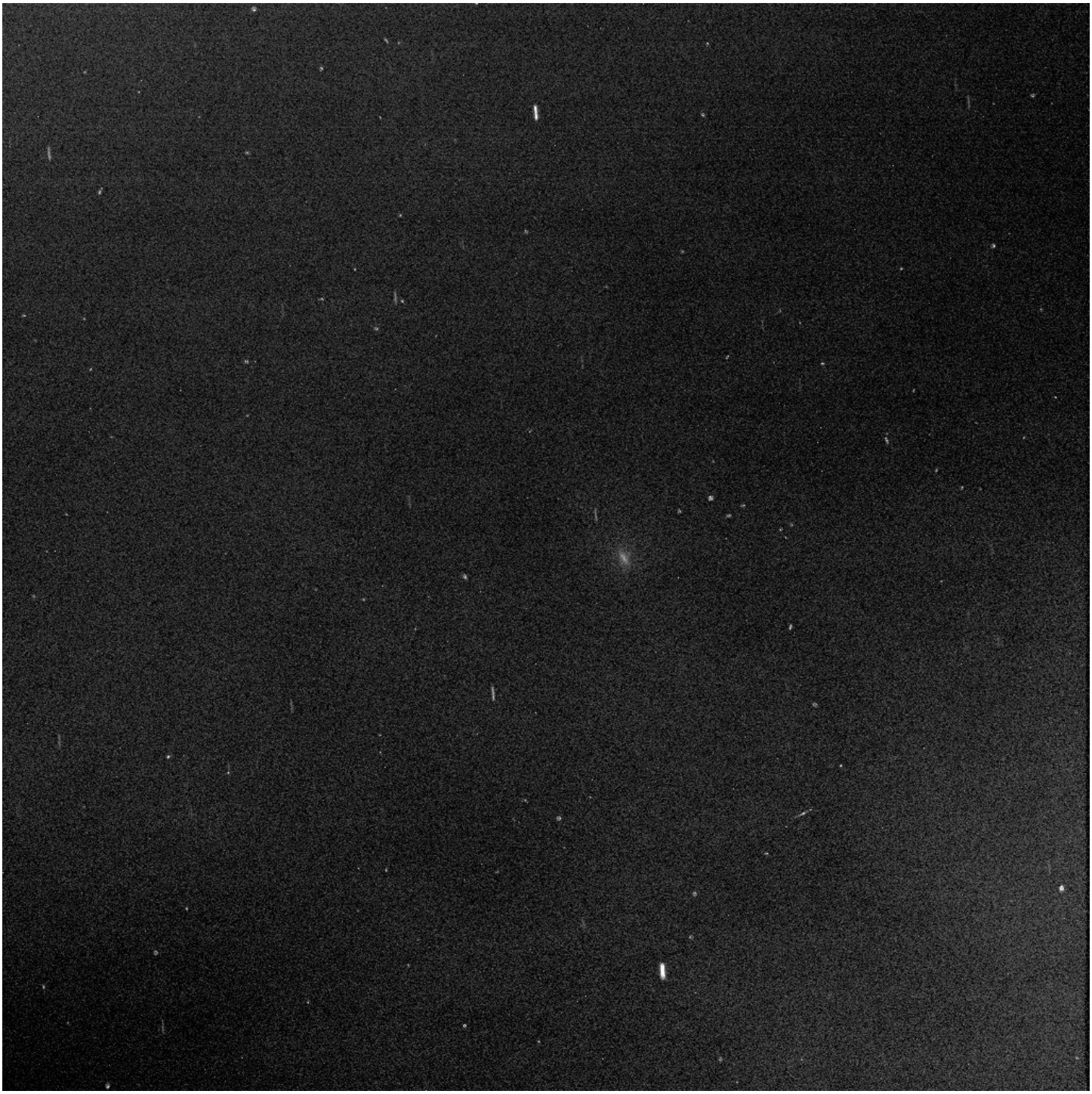
The comet brightened slowly over the months

Comet Siding Spring and Mars on October 19, 2014, approximately seven hours before closest approach. This image was taken by Nick Howes and Ron Wodaski with the Tzec Maun Foundation's remote telescope based at Siding Spring Observatory. Courtesy Tzec Maun Foundation.

following its discovery, and by the end of 2013 had become visually detectable at 14th magnitude. After conjunction with the sun in early May 2014 it emerged into the southern hemisphere's morning sky at around 13th magnitude, and brightened steadily from that point, finally reaching 10th magnitude around the time it was closest to Earth (0.89 AU) in early September, at which time it was in southern circumpolar skies. From that point it began traveling northward but also began fading, and was near 11th magnitude at the time of its passage by Mars.

Among the active spacecraft orbiting Mars at the time of the encounter were NASA's Mars Odyssey, Mars Reconnaissance Orbiter (MRO), and –just recently arrived – Mars Atmosphere and Volatile EvolutioN (MAVEN) missions, ESA's Mars Express, and – also just recently arrived – ISRO's Mars Orbiter Mission. On the surface NASA's Opportunity and Curiosity rovers were also operational. To prevent damage from sandblasting and stray electrical charges resulting from impacts from dust grains, all the orbiting spacecraft were placed on the opposite side of Mars at the time of the impact. Even so, the various missions were able to conduct some unique scientific observations: MRO was able to determine that the nucleus was an unexpectedly small 700 meters in diameter, and MAVEN detected large numbers of metal ions entering Mars' atmosphere, suggesting that someone on the surface might have witnessed an intense meteor shower (although the strength of this might have been diminished due to the thinness of Mars' atmosphere).

Both the Curiosity and Opportunity rovers were able to image Comet Siding Spring in the Martian sky. (Based upon the comet's brightness as seen from Earth, it would have appeared near magnitude -4 or -5, albeit spread out over several tens of degrees of sky.) The lighting conditions at Curiosity's site were poor and the resulting images don't show much, but the comet does show up reasonably well in the images taken by



Comet Siding Spring as imaged by the Opportunity rover on October 19, 2014. This is the first image ever taken of a comet from the surface of another planet. Courtesy NASA.

Opportunity. This was the first time that images of a comet were taken from the surface of another planet.

As seen from Earth, Comet Siding Spring and Mars were two arcminutes apart at the time of closest approach. Afterwards the comet gradually sank lower in the evening sky, although shortly before mid-November it underwent a small outburst which briefly brought it up to near magnitude 9.5. After conjunction with the sun in mid-December it reappeared in the morning sky in mid-January 2015 near magnitude 11.5; I was able to follow it visually until near the end of March, and the final astrometric observations were obtained in late January 2017, by which time its heliocentric distance was 8.50 AU and it had faded to 20th magnitude.

While Comet Siding Spring was the first, perhaps there may eventually be other comets observed from the surface of Mars. Perhaps by humans? Perhaps by "Ice and Stone 2020" participants? I leave the answers to these questions to those who are reading this . . .

SPECIAL TOPIC: 11/'OUMUAMUA

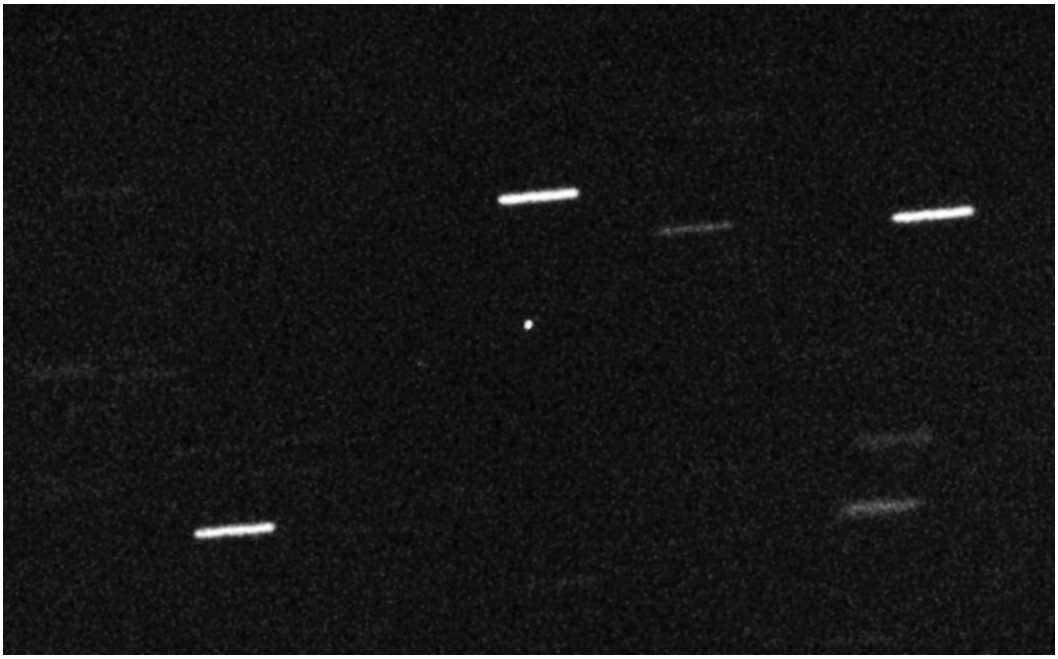


Image of 'Oumuamua with the 4.2-meter William Herschel Telescope in the Canary Islands on October 28, 2017. Courtesy Alan Fitzsimmons (ARC, Queen's University Belfast)/Isaac Newton Group.

While the details are always in a state of revision, for quite some time now the general consensus among astronomers as to how the solar system and its planets formed involves the accumulation of smaller objects, "planetesimals." The comets and asteroids we see today, and that have been the primary focus of "Ice and Stone 2020," are the "leftovers" from this process. As discussed in an earlier "Special Topics" presentation, early in the solar system's history many of the remaining planetesimals, comets in particular, were gravitationally kicked out into the far outer solar system where they collectively form the Oort cloud. The comets there are only weakly bound to the solar system, and thus stars passing near or through the Oort Cloud, and sometimes tidal forces from the Galaxy itself, will often eject these comets into interstellar space. At the same time, comets passing through the inner solar system will sometimes be gravitationally perturbed by Jupiter in such a way that they, too, will be ejected out of the solar system and into interstellar space.

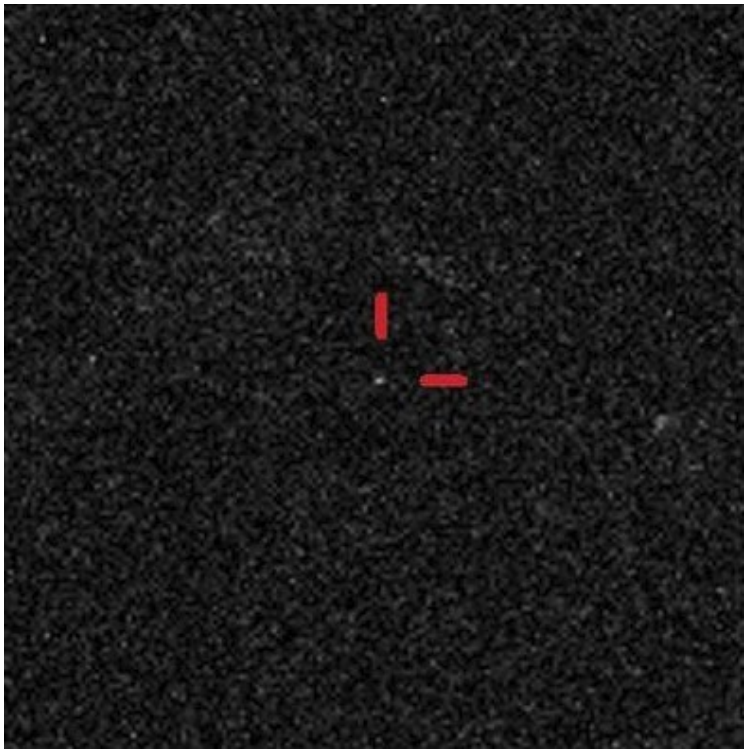
We now have good reason to believe that many, if not most or even almost all, other stars have planetary systems of their own. At the same time, it appears that not only is our solar system not a typical planetary system, there really is no such thing as a "typical" planetary system. Nevertheless, there is legitimate reason to believe that the fundamental processes that form planets are basically the same regardless of the specific details of any given planetary system, and if so, then all the other planetary systems should also be ejecting comets into interstellar space. Indeed, it would seem likely that interstellar space is teeming with comets and other "small bodies" that have been ejected from their respective original planetary systems.

It would also seem likely that, as our sun and our solar system make their travels through the Galaxy, from time to time we would encounter these objects in interstellar space. Various studies done over the years made attempts to calculate how many of these objects we should theoretically be encountering and detecting, with rates ranging from a handful per century to several per year. The detection of such objects would help reinforce, and modify as necessary, our consensus ideas as to how planetary systems form, and physical observations of them would provide valuable insights into how the processes are the same and/or different from one system to another.

Despite these various calculations, there had not been any confirmed examples of comets or other "small bodies" arriving from interstellar space. Over the years a couple of comets had been suspected of possibly being of interstellar origin based upon a seemingly anomalous chemical composition, but gravitationally these objects are still bound to the solar system, and there is no way to determine if they had in fact originally come from interstellar space.

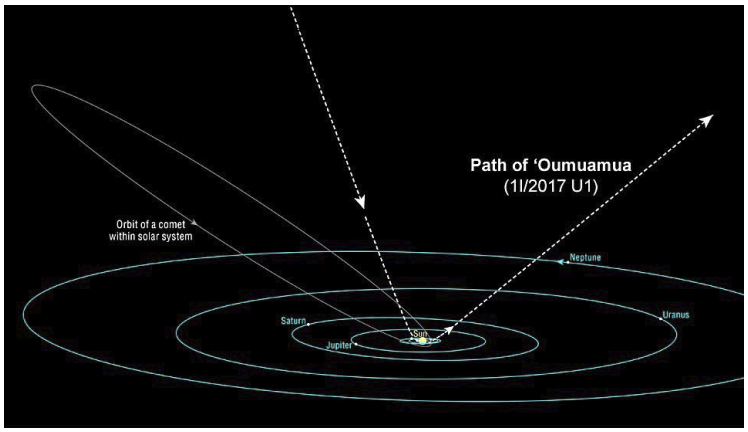
The entire situation changed three years ago when, on October 19, 2017, the Pan-STARRS survey program in Hawaii discovered a fast-moving 20th-magnitude object traveling through Cetus and Pisces. Orbital calculations were a bit tricky at first, but before long

it was firmly established that the object was traveling in a distinctly hyperbolic orbit with an eccentricity of 1.2 – clearly indicating an object arriving from interstellar space. It had already passed through perihelion, at the rather small heliocentric distance of 0.255 AU, on September 9, and five days before its discovery it had passed just 0.16 AU from Earth. A backtrack of its trajectory revealed that it had arrived in the solar system from the general direction of the solar apex in the constellation Hercules, which is where we would most likely encounter incoming interstellar objects.



One of the final images of 'Oumuamua obtained by the Hubble Space Telescope, on January 2, 2018. Courtesy NASA/ Daniel Bamberger.

Even though the object appeared stellar on the Pan-STARRS images, the general assumption had been that an interstellar object would be a comet, and it was initially announced as one under the designation C/2017 U1. However, it remained stellar in appearance even in very "deep" images obtained with the European Southern Observatory's Very Large Telescope, and the designation was accordingly changed to A/2017 U1. Once the object's interstellar origin was beyond doubt the IAU decided to introduce a new designation prefix, "I," indicating "interstellar," and to number these in the same manner as short-period comets. The object accordingly was assigned the designation "1I."



Schematic diagram of 'Oumuamua's passage through the solar system. Courtesy Brooks Bays/SOEST Publication Services/ University of Hawaii.

The consensus among the astronomical community is that the object also deserves a name. The Pan-STARRS discovery team proposed, and the IAU naming committee accepted, the name "'Oumuamua," from Hawaiian words that essentially translate as "a messenger from afar arriving first."

There was obviously a high interest among astronomers to obtain as many observations of 'Oumuamua as possible, but due to its faintness and the fact that it was already receding from the sun and Earth, and fading rapidly, these observations proved to be quite difficult. Indeed, the final observations, obtained with the Hubble Space Telescope in early January 2018 – by which time it had faded to about 26th magnitude – were made only 2½ months after its discovery. During that time it remained entirely stellar in appearance and never appeared as anything other than a point source of light. Photometrically it exhibited a distinctly reddish coloration, suggesting that its surface may be covered with tholins produced by irradiation by cosmic rays, similarly to objects in the Kuiper Belt. More surprisingly, 'Oumuamua exhibited very distinct variations in brightness – up to two magnitudes – over a period of 7 to 8 hours, indicating that it is a very elongated object, with the "best" data suggesting a "cigar" shape with a length of about 400 meters and a cross-sectional width only one-tenth to one-fifth that much. (Some kind of "disc"-shaped structure has also been suggested.) The evidence also suggests that it is not rotating cleanly about an axis but rather is "tumbling" as it travels through space.

Once all the positional data was analyzed, astronomers determined that 'Oumuamua had indeed exhibited an acceleration as it traveled through the solar system, analogous to the non-gravitational forces that comets exhibit. This suggests that 'Oumuamua may actually be a comet, but with an activity level too low to exhibit the physical characteristics normally associated with comets.

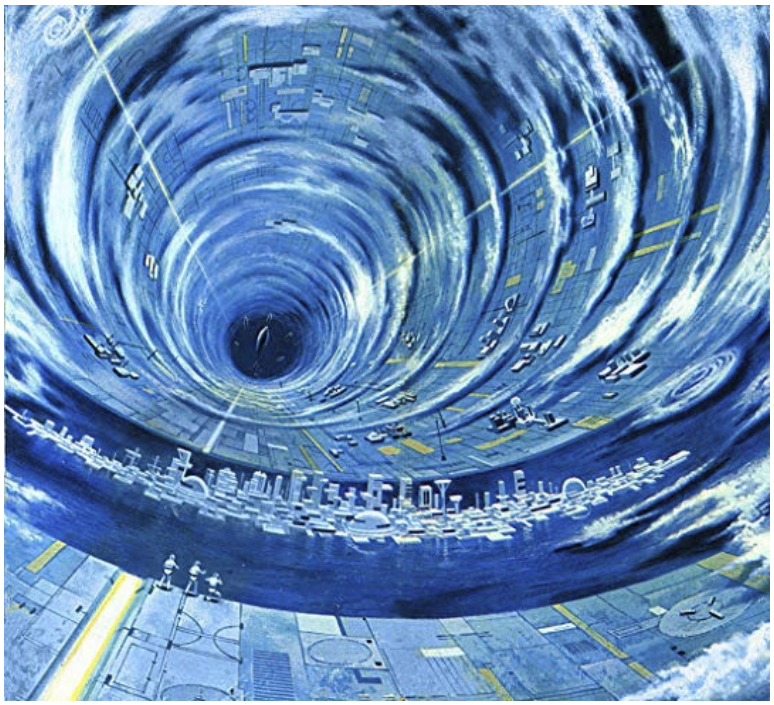
‘Oumuamua’s exact physical nature has remained a matter of much speculation ever since its passage through the solar system, and it is most unfortunate that we had such a limited opportunity to obtain meaningful observations of it before it had traveled too far away to detect. Its apparent asteroidal appearance, its very elongated shape, the weak but definite non-gravitational acceleration it exhibited, and its relatively rapid rotation and apparent tumbling are all difficult to reconcile into one coherent picture. Comet scientist Zdenek Sekanina at NASA’s Jet Propulsion Laboratory has suggested that ‘Oumuamua might be a porous, low-density fragment of a much larger interstellar comet that disintegrated as it passed through perihelion. Another, more recent suggestion has been proposed that ‘Oumuamua may be an “iceberg” of frozen molecular hydrogen, possibly escaped from a Giant Molecular Cloud from which stars and planetary systems form, although there are several difficulties with this explanation. On the other hand, while this must be regarded as at least somewhat fanciful, the suggestion has been made that ‘Oumuamua’s behavior is not inconsistent with what would be expected of a

Artist’s conception of ‘Oumuamua as a “cigar”-shaped solid object. Courtesy European Southern Observatory/Martin Kornmesser.

Artist’s conception of ‘Oumuamua as a potentially weakly active comet. Courtesy ESA/Hubble/NASA/ European Southern Observatory/Martin Kornmesser.

thin solar sail – indicative of an advanced alien technology. Some astronomers even made attempts with the SETI Institute's Allen Telescope Array and with the 100-meter radio telescope at Green Bank, West Virginia to see if it might possibly be transmitting signals indicative of an alien civilization, but detected nothing.

Several astronomers have attempted to determine if any "origin stars" for 'Oumuamua can be identified. Although some potential stars – including Vega, which is in the general direction of the solar apex – have been suggested, nothing conclusive can be determined, in part because the stars' motions cannot be that precisely pinned down. Meanwhile, following its passage through our solar system 'Oumuamua is departing in the general direction of the constellation Pegasus, continuing its journey through the reaches of our galaxy, and leaving us with several mysteries that will probably never be answered.



Artwork from the front cover of an edition of the 1973 novel "Rendezvous with Rama" by Arthur C. Clarke, depicting a scene inside the object "Rama."

One of the most important remaining questions was whether or not 'Oumuamua's passage through the solar system was a fluke occurrence, or instead was just the first known representative of a large population of interstellar objects that our technology has now progressed to the point of being able to detect. It has certainly begun to stimulate additional efforts to detect interstellar objects, and a year and a half ago Abraham Loeb and Amir Siraj at Harvard University announced that, in an examination of 30 years' worth of fireball records they had found one meteor entering Earth's atmosphere that may be of interstellar origin. This object, which may have been about 45 centimeters in diameter, appeared over Manus Island in Papua New Guinea on January 8, 2014, and did so with enough velocity to suggest that it came from outside the solar system. Unfortunately, with only the brief records of a meteor that weren't examined in detail until five years after-the-fact, there is no way that this can be considered conclusive.

The next major event in this endeavor occurred at the end of August 2019, when an amateur astronomer in Crimea, Gennady Borisov, discovered a comet that is traveling on an extremely hyperbolic orbit with an eccentricity of 3.35. This thus becomes the second-known object definitely known to come from interstellar space, and unlike 'Oumuamua this is clearly a comet. Comet 2I/Borisov, as this comet has since become designated and named, is a previous "Comet of the Week," and it is discussed more thoroughly in that Presentation.

The appearance of two interstellar objects passing through the solar system within a span of two years suggests that there is indeed a non-trivial population of these objects that our solar system is encountering, and that our survey capabilities have now reached the point where we can detect these objects on a consistent basis. With continued improvements in our detection capabilities, and in particular the 8.4-meter Vera Rubin Observatory in Chile that is expected to become operational within the next one to two years, we may within the not-too-distant future begin detecting enough interstellar objects that we can perform meaningful physical and statistical analyses of them, and in the process gather more insight into our own origins.

'Oumuamua's passage through the solar system bore a striking and almost uncanny resemblance to several of the events described within the renowned British science fiction writer Arthur C. Clarke's 1973 novel "Rendezvous with Rama." In that novel an object from interstellar space is discovered passing through the inner solar system, although in that case with enough lead time such that a human crew is able to rendezvous with it and examine it. The fictional Rama was much larger than 'Oumuamua and was quickly determined to be an artificial object, but like 'Oumuamua it passed through perihelion and headed back out into interstellar space while completely ignoring Earth in the process. One of the underlying points in "Rendezvous with Rama," which Clarke ended up exploring in a series of sequels he co-authored with Gentry Lee, is that "the Ramans do everything in threes;" whether or not this is true in real life remains to be determined.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