ICE & STONE 2020

WEEK 39: SEPTEMBER 20-26

Presented by The Earthrise Institute

Authored by Alan Hale

THIS WEEK IN HISTORY

20 | SEPTEMBER 21 | 22 | 23 | 24 | 25 | 26

SEPTEMBER 21, 2012: Two amateur astronomers, Vitali Nevski of Belarus and Artyom Novichonok of Russia, discover Comet ISON C/2012 S1 with a telescope of the International Scientific Optical Network located at Kislovodsk, Russia. Comet ISON was expected to become a brilliant object when near the sun and Earth in late 2013 but instead disintegrated as it passed through perihelion. It is a future "Comet of the Week."

SEPTEMBER 21, 2018: The MINERVA-II probe, carried with JAXA's Hayabusa2 mission, successfully lands on the surface of the near-Earth asteroid (162173) Ryugu and deploys small rovers; these become the first rovers to move on the surface of an asteroid. The Hayabusa2 mission is discussed in a future "Special Topics" presentation.

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SEPTEMBER 22, 1999: The Apollo-type asteroid now known as (101955) Bennu passes 0.015 AU from Earth, eleven days after its discovery by the LINEAR program in New Mexico. Bennu is the destination of NASA's currently-ongoing OSIRIS-REx mission, which is discussed in a future "Special Topics" presentation.

SEPTEMBER 22, 2001: NASA's technology test bed Deep Space 1 mission flies by Comet 19P/Borrelly. The returned images show the comet's nucleus as a bowling pin-shaped object roughly 8 km long. Deep Space 1 is discussed in a previous "Special Topics" presentation.

SEPTEMBER 22, 2001: A team of astronomers led by William Merline discovers a binary moon companion – since named Menoetius – of the large "Jupiter Trojan" asteroid (617) Patroclus with the 8.1-meter Gemini North Telescope at Mauna Kea Observatory in Hawaii. Patroclus and Menoetius are scheduled to be visited by NASA's Lucy mission in 2033. The Lucy mission is discussed in a previous "Special Topics" presentation, and Trojan asteroids are the subject of a future "Special Topics" presentation.

SEPTEMBER 22, 2080: The Apollo-type asteroid (101955) Bennu will pass 0.016 AU from Earth. Bennu is the destination of NASA's currently-ongoing OSIRIS-REx mission.

COVER IMAGE CREDIT:

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

Courtesy NASA/JPL-Caltech

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SEPTEMBER 23, 585: Astronomers serving in the court of the Sui dynasty in China make the first records of seeing the Orionid meteor shower, reporting "hundreds of meteors scattered in all directions." The Orionids, which peak on October 21 this year, are associated with Comet 1P/Halley.

SEPTEMBER 23, 2060: The Apollo-type asteroid (101955) Bennu will pass only 0.005 AU – just under 2.0 lunar distances – from Earth, the closest approach it will make during the 21st Century. Bennu is the destination of NASA's currently-ongoing OSIRIS-REx mission.

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SEPTEMBER 24, 1975: Guido Pizarro of the European Southern Observatory in Chile takes a survey photograph with the 1.0-meter Schmidt telescope. Upon examining this photograph six weeks later ESO astronomer Richard West discovered a faint comet. Comet West 1975n became a brilliant comet when it passed through perihelion in February 1976, and I consider it to be the best comet I have ever observed. It is a previous "Comet of the Week."

SEPTEMBER 24, 2009: The science team of NASA's Moon Mineralogy Mapper aboard India's Chandrayaan-1 lunar probe announces the detection of water ice in permanently shadowed craters near the moon's poles; these results would be completely confirmed after nine years of subsequent analysis. The presence and significance of water ice on the moon is discussed in a previous "Special Topics" presentation.

SEPTEMBER 24, 2023: NASA's OSIRIS-REx mission, which arrived at the Apollo-type asteroid (101955) Bennu at the end of 2018, and which is scheduled to collect surface material samples next month and then depart Bennu next March, is scheduled to arrive back at Earth with those samples. OSIRIS-REx is discussed in a future "Special Topics" presentation.

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SEPTEMBER 26, 1992: A Japanese amateur astronomer, Tsuruhiko Kiuchi, recovers Comet 109P/Swift-Tuttle – the parent comet of the Perseid meteor shower – during its most recent return. The comet became a dim naked-eye object of 5th magnitude when it passed through perihelion late that year. It is a future "Comet of the Week."

SEPTEMBER 26, 2020: Comet 88P/Howell passes through perihelion at a heliocentric distance of 1.353 AU. It is presently slightly brighter than 10th magnitude and thus is easily detectable with a small telescope. Updates about it and other visible comets are available at the Comet Resource Center.

COMET OF THE WEEK: DELAVAN 1913F

Perihelion: 1914 October 26.77, q = 1.104 AU

Wide-field view of Comet Delavan photographed by Edward Barnard at Yerkes Observatory in Wisconsin on August 21, 1914.

After the spectacular appearances of the Daylight Comet of 1910 and of Comet 1P/Halley later that same year – both of these objects having been discussed in previous "Ice and Stone 2020" presentations – the next few years brought some additional bright comets to Earth's nighttime skies. While none of these could really be considered as "Great" comets, some of them did become at least somewhat conspicuous to the unaided eye. One of these was discovered on December 18, 1913, by Paul Delavan, one of the astronomers on the staff of the Argentina National Observatory in La Plata (outside of Buenos Aires). Part of Delavan's program consisted of hunting for comets with one of the La Plata telescopes that was specifically designed for that purpose.

At the time of its discovery Comet Delavan was about 11th magnitude, located near the star Eta Eridani high in the evening sky, and moving slowly to the northwest. Initial orbital calculations proved to be somewhat problematical, but it was eventually determined that the comet was located at a heliocentric distance of 4.2 AU – unusually large for the comets known at that time – and was still over ten months away from perihelion passage. Intrinsically, Comet Delavan was the second-brightest comet to

Close-up of the coma and inner tail structure of Comet Delavan, photographed from Heidelberg Observatory, Germany on September 25, 1914.

appear during the 20th Century – only Comet Hale-Bopp C/1995 O1 was brighter – and had it come closer to the sun and Earth in undoubtedly would have been a "Great" comet.

The comet initially brightened rather slowly, reaching 9th magnitude near the end of March 1914 shortly before it disappeared into evening twilight. After conjunction with the sun it emerged into the northern hemisphere's morning sky near the end of June, being close to magnitude 7 at the time, and afterwards it brightened more rapidly. It became widely visible to the unaided eye as a 5th-magnitude object in August, and was brightest during September and October when it was slightly brighter than magnitude 3. It passed closest to Earth – at a relatively distant 1.58 AU – on October 4, and although it was primarily a morning-sky object, it was far enough north of the sun and close enough to conjunction that it could also be detected low in the northwestern sky after dusk.

Following its peak performance Comet Delavan began traveling slowly southward and started fading, being around 5th magnitude in mid-December. By that time it was approaching morning twilight, and although it was never quite in conjunction with the sun its elongation remained low enough such that observations were difficult for the next couple of months. It was still 6th magnitude in January 1915 but had faded to 8th magnitude by mid-March, by which time it was beginning to travel deeply into southern skies. Observers in the southern hemisphere followed it steadily for the next several months, with the final observations being obtained in early September when it was around 12th magnitude.

Comet Delavan exhibited two tails, a straight ion tail about ten degrees long and a broad, curving dust tail six to eight degrees long at its longest. Although numerous other comets, past and present, have also exhibited two such tails, Comet Delavan was somewhat unusual in that both tails were of about equal brightness. One of the most active comet observers of that era, American astronomer Edward Barnard, commented that the straight tail was more prominent photographically than visually, whereas the curved tail was the exact opposite. This difference reinforced ideas he had previously expressed that different mechanisms were almost certainly responsible for the development of the various tails – something we now know to be true, although it would be a few more decades before satisfactory explanations for these different mechanisms would be advanced. This is the subject of this week's "Special Topics" presentation.

Another wide-field view of Comet Delavan captured by Philibert Melotte at the Royal Observatory in England, September 20, 1914.

SPECIAL TOPIC: COMET TAILS

Example of a "disconnection event" in a comet's ion tail. This is a photograph I took of Comet Hyakutake C/1996 B2 on the night of its closest approach to Earth (March 24-25, 1996); the bright stars in the center are the Big Dipper's "handle." Note the "break" in the ion tail to the left of the star at the end of the "handle."

Of all the phenomena associated with comets, the one that more than any other gives them their beauty and their mystique is their tails. As recounted in a previous "Special Topics" presentation, the first recorded scientific observation of a comet concerned its tail: when observing the bright comet that appeared during the second half of 1531 – which we now know to be a return of Comet 1P/Halley – the German philosopher Petrus Apianus (Peter Apian) in Bavaria noted that the comet's tail was always directed away from the sun.

Anyone who has observed several comets, or examined images of several comets, will have noticed that not all cometary tails are equal. Some are straight and narrow, others are broad and curved, some are short, some are long – and they can change their appearances over time. Many comets exhibit at least two tails, although the differences in intensity between these two tails can vary from comet to comet, and even from time to time with the same comet. While he perhaps wasn't the first person to do so, in 1914 astronomer Edward Barnard at Yerkes Observatory in Wisconsin pointed out that, for Comet Delavan 1913f – this week's "Comet of the Week" – the straight tail was more prominent photographically (especially in photographs taken with blue-sensitive emulsions) than visually, whereas the curved tail was the exact opposite. This reinforced earlier ideas he had expressed that different mechanisms were almost certainly responsible for the development of the two tails. He turned out to be correct, although it would be several decades before satisfactory explanations for these different mechanisms would be advanced.

A comet that had appeared a few years earlier, Comet Morehouse 1908c, had a tail which was inconspicuous visually but which was quite prominent when photographed, and which exhibited dramatic changes on a night-to-night basis and sometimes even during the course of a single night. These changes were so dramatic and so rapid that Barnard suggested some electrical forces – similar to what are present in aurora displays – might be responsible. Based upon his own studies of Comet Morehouse, the British astronomer Arthur Eddington – who would later have a distinguished career in stellar astrophysics and cosmology – independently reached similar conclusions, at one point even suggesting that

A recent gas-rich but dust-poor comet. Comet Lovejoy C/2014 Q2 on January 14, 2015; the comet had a low dust content but exhibited a distinct and complex ion tail. Courtesy Gerald Rhemann in Austria.

"a swarm of ions proceeding from the Sun and encountering the comet" was responsible for the activity the comet displayed.

For the most part these suggestions lay dormant for the next few decades. Finally, in the late 1940s and early 1950s the German astronomer Ludwig Biermann proposed a "solar corpuscular radiation" as being responsible for the rapidly changing phenomena in a comet's tail and the fact that it was always directed away from the sun. Later in the 1950s an American astrophysicist, Eugene Parker – for whom NASA's Parker Solar Probe, launched in August 2018, was named – expanded these ideas and incorporated other solar phenomena and proposed the existence of a "solar wind," a constant stream of ionized particles "blowing" off the sun. Parker's ideas were quite controversial at the time, in fact, two of the referees of his submitted paper recommended its rejection, although the editor of the Astrophysical Journal published it anyway. The Soviet Union's Luna 1 mission in early 1959 recorded measurements of what appeared to be this "solar wind," and in 1962 NASA's Mariner 2 mission to Venus – the first successful interplanetary probe – confirmed the solar wind's existence while en route to that world.

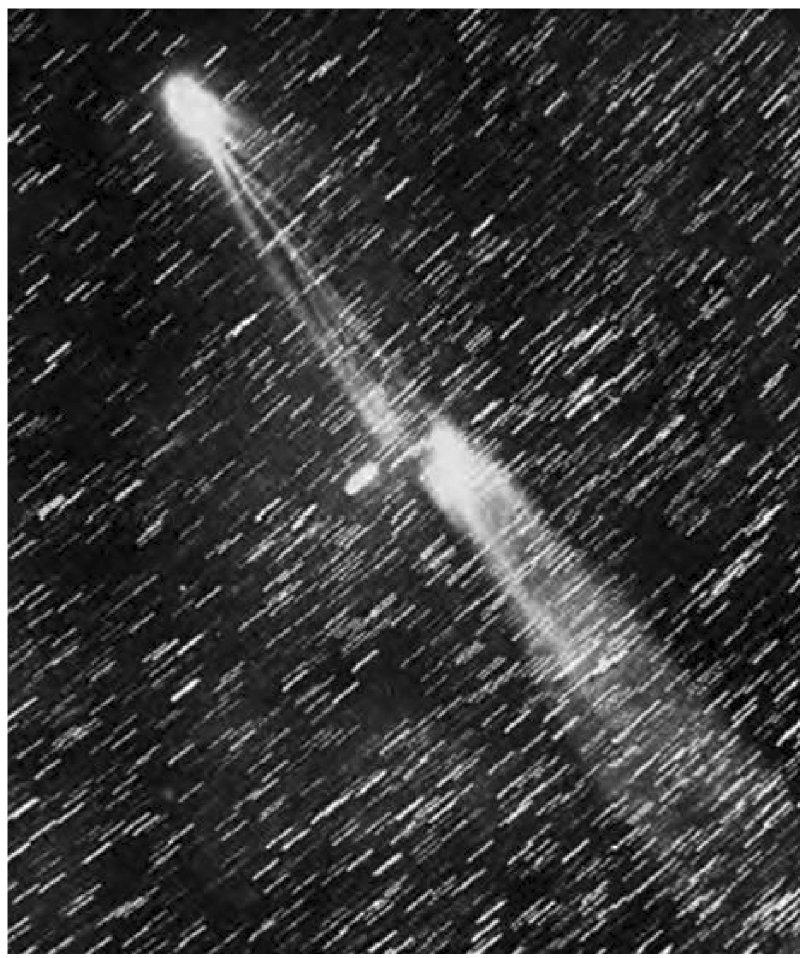
An example of a comet with two different tails both displayed prominently: a photograph I took of Comet Hale-Bopp on April 9, 1997.

The solar wind is made up of electrons, protons, and various ions – all electrically charged. It generally "blows" at approximately 400 km/second, although the overall flow is complex and depends in part on the sunspot cycle. At the same time, solar flares and coronal mass ejections can affect the solar wind, sometimes dramatically. These various effects produce what we call "space weather," and among other things are responsible – as Barnard suggested – for displays of the aurora (caused when the solar wind, interacting with Earth's magnetic field, ionizes atoms in the gases of the upper atmosphere, which then emit photons of light when they recombine with the stripped electrons).

Ultraviolet radiation from the sun breaks apart the molecules of the sublimated ices contained within a comet's nucleus, and then ionizes the atoms of these "daughter" atoms and molecules. The solar wind then interacts with these ions, thus "blowing" them back behind the comet, creating what is usually called the comet's "ion tail" or sometimes its "plasma tail" (a plasma in this context being ionized gas). Carbon is a common "daughter" product (from carbon monoxide, carbon dioxide, and methane, among other "parent" molecules), and since ionized carbon molecules emit light primarily in the blue end of the spectrum, the ion tails are accordingly bluish in color (and thus prominent in blue-sensitive photographic emulsions and CCD chips). The structure of a comet's ion tail can reflect changes and variations in strength of the solar wind, and thus is in effect a windsock for the solar wind.

In the late 1950s the Swedish physicist Hannes Alfven pointed out that the solar wind – still a theoretical construct at that time – would, upon encountering the electrically charged ions around a comet's coma, split into two oppositely charged halves which would then "drape" around the comet – a prediction verified in 1985 when the International Cometary Explorer (ICE) mission passed through the ion tail of Comet 21P/Giacobini-Zinner (last week's "Comet of the Week"). At times the solar wind can be strong enough that it pinches the magnetic field lines in the ion tail together, producing what is called a "disconnection event." Such events are quite common and have been observed in numerous comets. There have even been occasions, especially when a comet has encountered phenomena like coronal mass ejections, that it has all but had its ion tail ripped away completely.

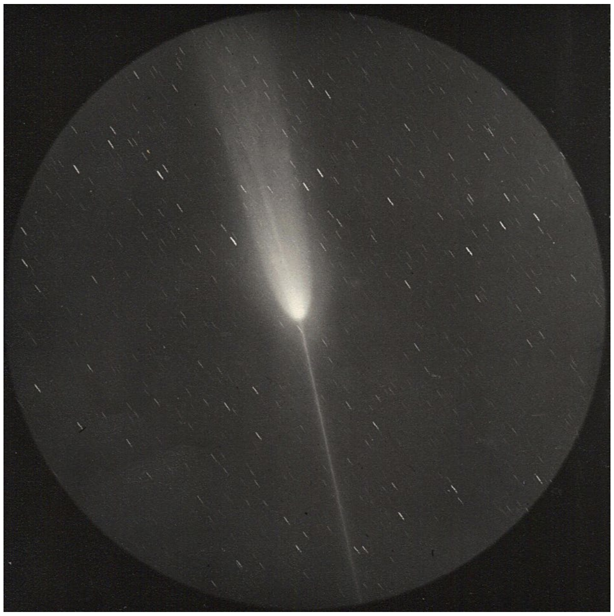
Embedded within the frozen ice of a comet's nucleus are large amounts of dust grains, and as this ice sublimates upon encountering sufficient heat from sunlight these dust grains are ejected from the nucleus along with the sublimating gas. Since the nucleus is rotating this constant stream of dust spirals out away from the nucleus in the same manner that water jets spiral out away from a spinning water sprinkler, and this can create "hood"-like structures within the inner coma. Some comets, Hale-Bopp among them, have exhibited strong distinct "hoods" within their comae due to this phenomenon. As these dust streams continue spiraling away from the nucleus they spread out and merge with each other, creating a continuous expanse of dust.



Comet Morehouse 1908c on October 1, 1908. Courtesy Lick Observatory.

A recent dust-rich but gas-poor comet. Comet PANSTARRS C/2011 L4 and the day-old crescent moon, deep in twilight on the evening of March 12, 2013. The comet had a high dust content and exhibited a bright dust tail throughout its apparition. Courtesy Peter Lipscomb in New Mexico.

In the mid-19th Century the Scottish physicist James Clerk Maxwell mathematically demonstrated that light exerts pressure, and in the late 19th and early 20th Centuries this was explored more thoroughly and experimentally by Russian physicists Pyotr Lebedev and Fyotr Bredikhin and Swedish scientist Svante Arrhenius. For objects as small as cometary dust grains the sun's radiation pressure is stronger than its gravitational attraction, and consequently the dust grains are pushed back behind the comet. In effect, each dust grain goes into its own orbit around the sun, and as they lag farther and farther behind the comet itself they begin to form the comet's dust tail that, due to the comet's own orbital motion, usually exhibits distinct curvature. These dust grains "shine" by reflected sunlight, and thus they appear whitish, perhaps slightly yellowish, in color, and since our eyes are more sensitive to this than they are to the bluish coloration of ion tails, the dust tails are accordingly more prominent visually than are ion tails.



An example of cometary "anti-tails." Comet Arend-Roland 1956h on April 25, 1957, taken by Eric Lindsay from Armagh Observatory in Northern Ireland. Courtesy John McConnell.

There is a wide variation among comets as to their relative populations of ice, i.e., gas, and dust. Those comets that are relatively low in dust content may exhibit strong and complex ion tails but never develop much of a dust tail. On the other hand, those comets with a high dust content can exhibit bright and long dust tails but may only exhibit a relatively weak ion tail. Since it takes a while for a substantial dust tail to develop even dust-rich comets may not exhibit much of a dust tail early on, and for such comets the dust

Comet McNaught C/2006 P1 on January 19, 2007, from Siding Spring Observatory in New South Wales. "Synchronic bands" within the dust tail are very prominent. Courtesy Rob McNaught.

tails tend to be brighter and longer after perihelion than before.

In addition to the regular continuous release of dust, some dust-rich comets, especially those that pass close to the sun, may experience regular episodes of ejections of large amounts of dust from specific active areas that rotate into and then out of sunlight. The individual dust grains in these "mass ejections" will vary in size, and the radiation pressure in sunlight will accelerate the smaller grains away from the nucleus faster than the larger grains. The result from a single event is the appearance of a "ray"-like structure within the dust tail, and with multiple events the overall appearance is that of a series of slightly non-parallel "bands" in the tail. These features are usually referred to as "synchronic bands," and some of the brighter comets that have appeared over time – including some that have been featured as "Comets of the Week" – have exhibited these, two recent examples being Comet McNaught C/2006 P1 shortly after it passed through perihelion in early 2007 and Comet NEOWISE C/2020 F3 which was a bright object in our skies two months ago.

Sometimes the viewing geometry of a comet is such that when Earth crosses the comet's orbital plane, the dust grains that have been lagging far behind the comet can appear to lie between the comet and the sun, creating what is called an "anti-tail." Contrary to what is normally seen of a comet's tail, this feature will appear to be directed towards the sun, but this is merely a projection effect. Several comets have exhibited distinct and prominent anti-tails, one of the more dramatic examples being Comet Arend-Roland 1956h – a previous "Comet of the Week" – after it had passed through perihelion in 1957.

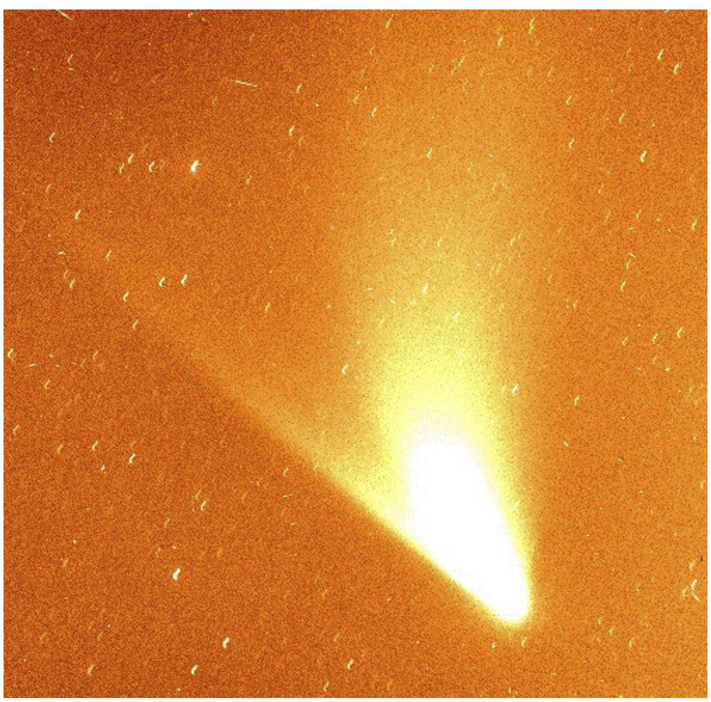
Other tail phenomena have occasionally been seen with various comets as well. Shortly after Comet Hale-Bopp had passed through perihelion in April 1997 a team of astronomers at La Palma Observatory in the Canary Islands detected a narrow straight tail composed of fluorescing sodium atoms. Meanwhile, images of Comet Hyakutake C/1996 B2 taken by the LASCO C3 coronagraph aboard the SOlar and Heliospheric Observatory (SOHO) spacecraft as the comet was passing through perihelion revealed, in addition to the regular ion and dust tails, a third straight tail that subsequent analysis indicated was made up of massive particles that had been ejected from the nucleus during the preceding few days.

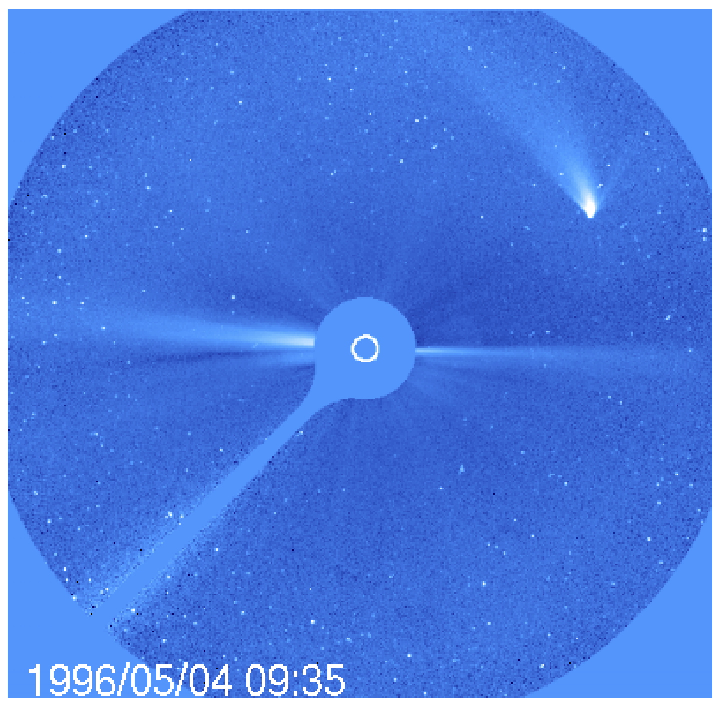
Besides SOHO, other spacecraft have sometimes

Another example of cometary "anti-tails." Comet PANSTARRS C/2011 L4 on May 23, 2013. The "anti-tail" (left) dwarfs the main dust tail (right). Courtesy Michael Jaeger in Austria.

revealed cometary tail features that might have otherwise escaped detection. During its operational lifetime in 1983 the InfraRed Astronomical Satellite (IRAS) spacecraft detected long dust "trails" accompanying several comets within the inner solar system, most strikingly with Comet 10P/Tempel 2 which passed through perihelion during the middle of that year. (An IRAS image of Comet 10P's dust trail is featured in a previous "Special Topics" presentation.) Magnetic field data taken by ESA's Ulysses mission in May 1996 – at which time it was located at a heliocentric distance of 3.7 AU – indicated that Comet Hyakutake's ion tail was at least 3.8 AU long and moreover exhibited distinct curvature, contrary to most commonly-held ideas about ion tails.

While many of the processes that affect the formation and development of comets' tails are understood relatively well, there are still gaps within that knowledge that only additional observations will be able to fill in. There are plenty of physical processes going on within a comet that produce the various features we observe, and in a sense we can consider a comet as a cosmic physics laboratory – one that is accessible to all of us, and, with each new comet that comes by, one that provides us an inexhaustible supply of subjects to examine.





"Other" types of cometary tails. Left: The discovery photograph of the sodium tail on Comet Hale-Bopp, taken April 16, 1997. The sodium tail is the straight narrow tail extending towards the upper left. Courtesy Gabrielle Cremonese/Padova Astronomical Observatory/Isaac Newton Team. Right: LASCO C3 coronagraph (from the SOHO mission) image taken May 4, 1996 of Comet Hyakutake C/1996 B2. The third, straight tail extends toward the upper right from the comet. Courtesy NASA/ESA.

www.halebopp.org

www.iceandstone.space

PDF booklet prepared by RocketSTEM