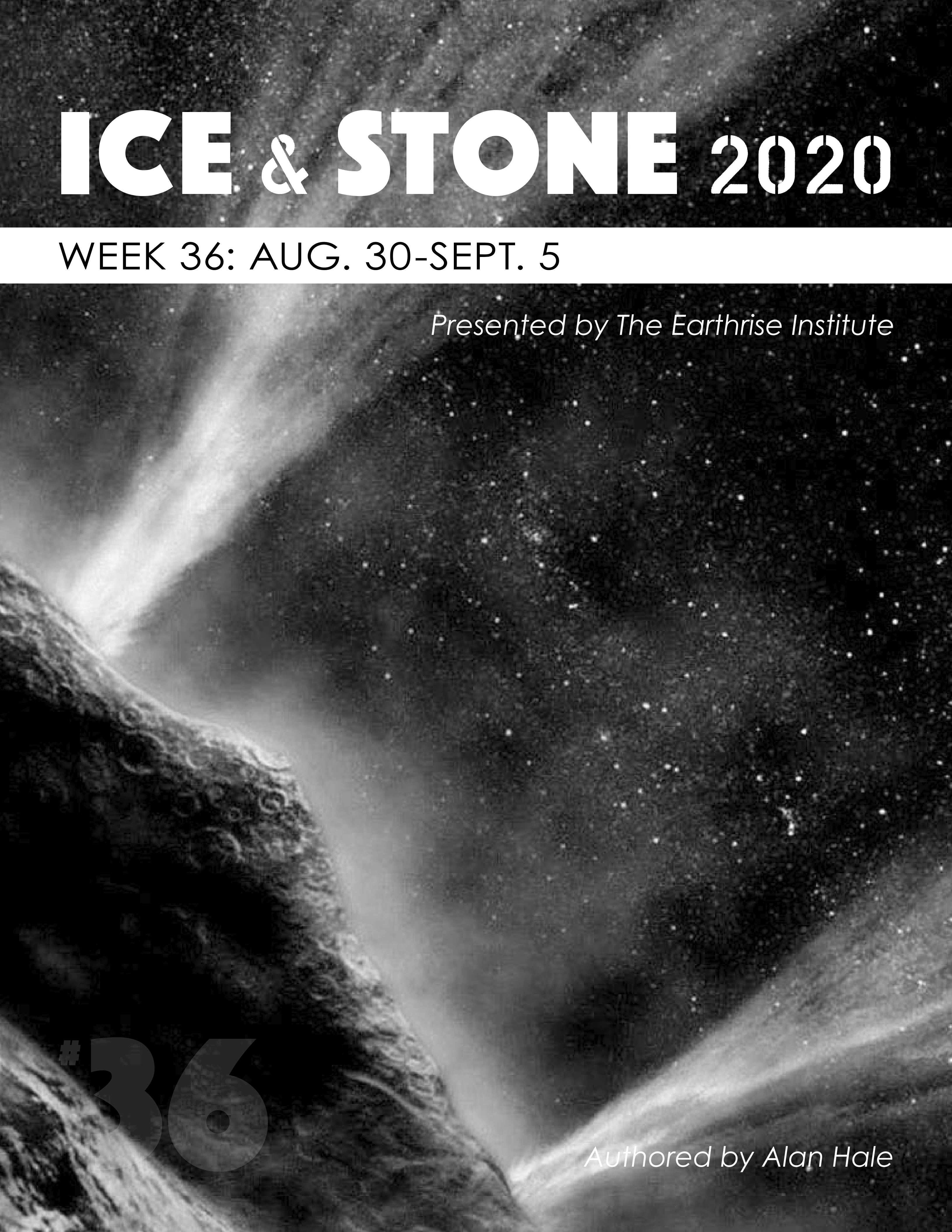


ICE & STONE 2020

WEEK 36: AUG. 30-SEPT. 5

Presented by The Earthrise Institute

#36

Authored by Alan Hale

THIS WEEK IN HISTORY

AUGUST 30 | 31 | 1 | 2 | 3 | 4 | 5

AUGUST 30, 1979: The SOLWIND coronagraph aboard the U.S. Defense Department's P78-1 satellite records images of a bright comet approaching the sun, and then disintegrating. This comet, the first comet ever to be discovered from space, turned out to be a Kreutz sungrazer, and was the first of several comets discovered by SOLWIND prior to the destruction of P78-1 in 1985. It is this week's "Comet of the Week."

AUGUST 30, 1992: David Jewitt and Jane Luu discover a faint distant asteroid, originally designated 1992 QB1 and now formally known as (15760) Albion, from Mauna Kea Observatory in Hawaii. Albion was the first confirmed example of an object within the Kuiper Belt, which is the subject of this week's "Special Topics" presentation.

AUGUST 30, 2019: An amateur astronomer in Crimea, Gennady Borisov, discovers a faint comet, provisionally designated as C/2019 Q4, utilizing a telescope he built himself. Comet Borisov was found to be traveling on a very hyperbolic orbit indicating that it has arrived in the solar system from interstellar space, the first confirmed example of an interstellar comet. Now designated as Comet 2I/Borisov, it is next week's "Comet of the Week."

30 | AUGUST 31 | 1 | 2 | 3 | 4 | 5

AUGUST 31, 2020: The main-belt asteroid (666) Desdemona will occult the 6th-magnitude star HD 142703 in Libra. The predicted path of the occultation crosses the very southern tip of South Korea, the northern part of the Japanese island of Kyushu and the southern part of the Japanese island of Shikoku, and then open waters of the northwestern Pacific Ocean.

COVER IMAGE CREDIT:

Front and back cover: An artist's concept depicting a view of comet Wild 2 as seen from NASA's Stardust spacecraft during its flyby of the comet on Jan. 2, 2004..

Courtesy NASA/JPL-Caltech

30 31 SEPTEMBER 1 2 3 4 5

SEPTEMBER 1, 1804: German astronomer Karl Harding discovers the main-belt asteroid now known as (3) Juno. It is the smallest and dimmest of the four originally known main-belt asteroids – discussed in the Week 1 "Special Topics" presentation – and was at opposition this past April.

SEPTEMBER 1, 1882: Various observers – many of them aboard ship – in the southern hemisphere report seeing a bright comet in the morning sky. This comet would become known as the Great Comet of 1882, one of the brightest comets of the entire 2nd Millennium, and would be visible in broad daylight for several days around the time of its perihelion passage in mid-September. A future "Comet of the Week," this comet was a Kreutz sungrazer, which are discussed in a future "Special Topics" presentation.

SEPTEMBER 1, 1991: Geologists Alan Hildebrand, Glen Penfield, and colleagues publish a paper proposing that a large subterranean crater located off the northern coast of the Yucatan Peninsula of Mexico near the village of Puerto Chicxulub is the impact site of the body that caused the Cretaceous-Tertiary (K-T) extinction event 66 million years ago which, among other life forms, caused the extinction of the dinosaurs. The K-T event, and the relationship of the Chicxulub crater to that, is the subject of a previous "Special Topics" presentation.

SEPTEMBER 1, 2362: According to Japanese astronomer Syuichi Nakano, Comet 153P/Ikeya-Zhang will next pass through perihelion at a heliocentric distance of 0.506 AU. Comet Ikeya-Zhang is the longest-period comet that has been definitely seen on two returns, and its 2002 return is a previous "Comet of the Week."

30 31 1 2 SEPTEMBER 3 4 5

SEPTEMBER 3, 2020: The main-belt asteroid (157) Dejanira will occult the 7th-magnitude star HD 25186 in Taurus. The predicted path of the occultation crosses the southern tip of India, central Myanmar, northern Thailand, northern Laos, northern Vietnam (including the southern regions of Hanoi), far southern China, and the southern tip of the Japanese island of Kyushu (including the Uchinoura Space Center).

30 31 1 2 3 4 SEPTEMBER 5

SEPTEMBER 5, 1989: Pluto passes through perihelion at a heliocentric distance of 29.66 AU. Pluto is the subject of its own earlier "Special Topics" presentation, and its relationship with the Kuiper Belt is discussed in this week's "Special Topics" presentation.

SEPTEMBER 5, 2008: ESA's Rosetta mission passes by the main-belt asteroid (2867) Steins during its first passage through the main asteroid belt. Rosetta, which eventually traveled to its primary destination of Comet 67P/Churyumov-Gerasimenko, is discussed in a previous "Special Topics" presentation.

SEPTEMBER 5, 2012: Having spent the preceding 14 months orbiting the large main-belt asteroid (4) Vesta, NASA's Dawn mission departs, en route to its next destination of the large main-belt asteroid (1) Ceres, where it would arrive 2½ years later. The Dawn mission is discussed in a previous "Special Topics" presentation.

COMET OF THE WEEK: SOLWIND 1 1979 XI

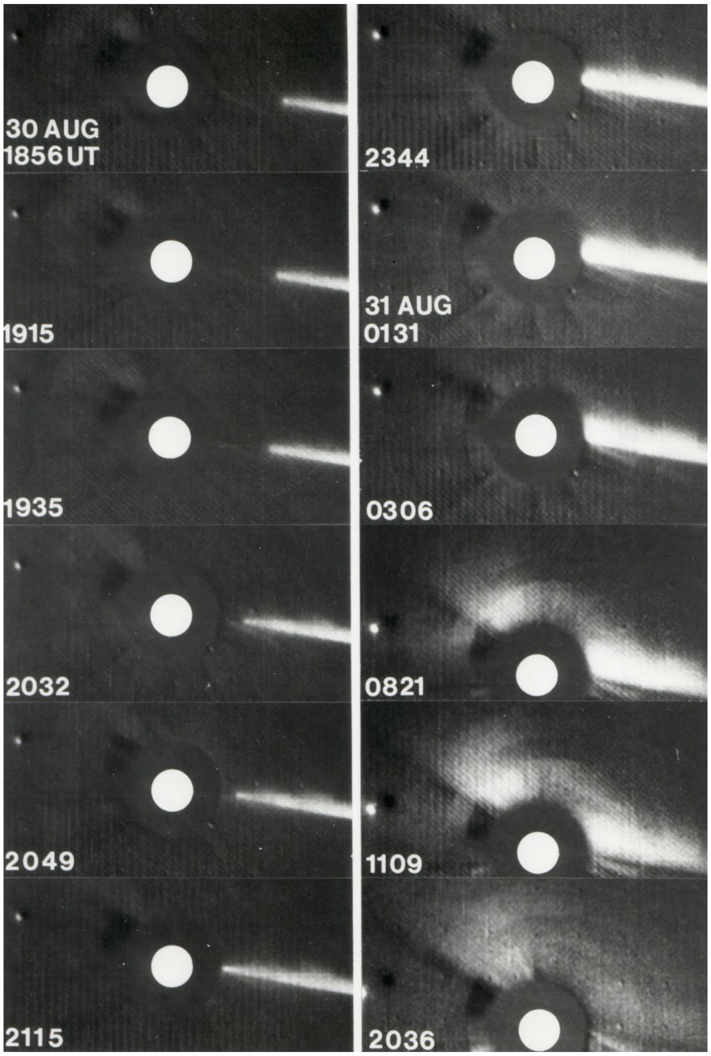
Perihelion: 1979 August 30.95, q = 0.005 AU

The very first comet I ever observed, Comet Tago-Sato-Kosaka 1969g – a previous "Comet of the Week" – was also the first comet ever to be observed from space, an event which took place in mid-January 1970. Since that time many, many comets have been observed by orbiting satellites, and a few have even been visited by spacecraft missions; some of these are additional "Comets of the Week." It was inevitable that, at some point, comets would begin to be discovered by satellites in orbit, and indeed the first such instance happened about a decade after the first space-based comet observations. This first satellite-based comet discovery came about in a rather dramatic and unexpected fashion, however.

In September 1981 a team of scientists at the Naval Research Laboratory (NRL) in Washington, D.C. – which included Russ Howard, who made the actual discovery, along with Martin Koomen and Don Michels, who developed the instrumentation – reported that they had detected images of a bright comet – at least as bright as Venus – in images taken two years earlier by the SOLWIND white-light coronagraph aboard the U.S. Defense Department satellite P78-1 (which had been launched on February 24, 1979). The images, taken over a period of several hours on August 30 and 31, 1979, showed the bright, long-tailed comet approaching the sun and then disappearing behind the occulting disk that blocked the sun. Although the comet did not reappear afterwards, images taken over the next several hours showed the material in the tail spreading out and surrounding the occulting disk before dispersing.

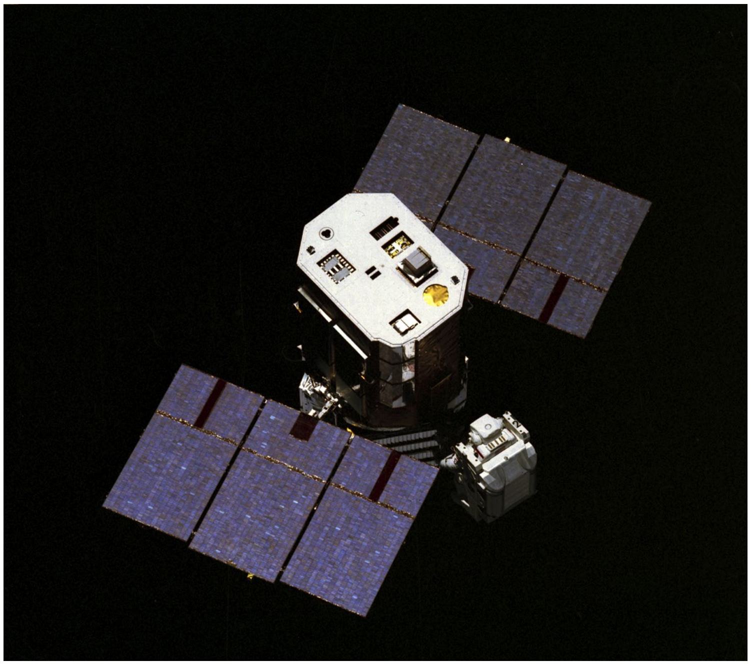
The meager and low-resolution astrometric data made orbital calculations somewhat problematical, but it soon became clear that the comet was a Kreutz sungrazer – a class of comets that includes several other "Comets of the Week" and which is discussed as a whole in a future "Special Topics" presentation. The comet clearly disintegrated as it passed through perihelion, and since it had approached from behind the sun the tail material that enshrouded the occulting disk afterwards was between Earth and the sun and thus its brightness was enhanced by forward scattering of sunlight.

There have been no reports of ground-based detections of the comet as it approached perihelion – and, indeed, late August presents poor viewing geometry for inbound Kreutz sungrazers in any event. There were also no reports of any ground-based detections of tail material after perihelion. The one possible ground-based detection of the comet came from a team of astronomers in then-Czechoslovakia who reported that spectra of the sun's corona taken with a coronagraph at Lomnicky Stit Observatory a few hours after the comet's perihelion revealed dim features that could possibly be due to silicon and nickel from dust grains within the comet's tail.



Images of Comet SOLWIND 1 approaching the sun and disintegrating, August 30-31, 1979, taken by the SOLWIND coronagraph aboard P78-1. Images courtesy Naval Research Laboratory.

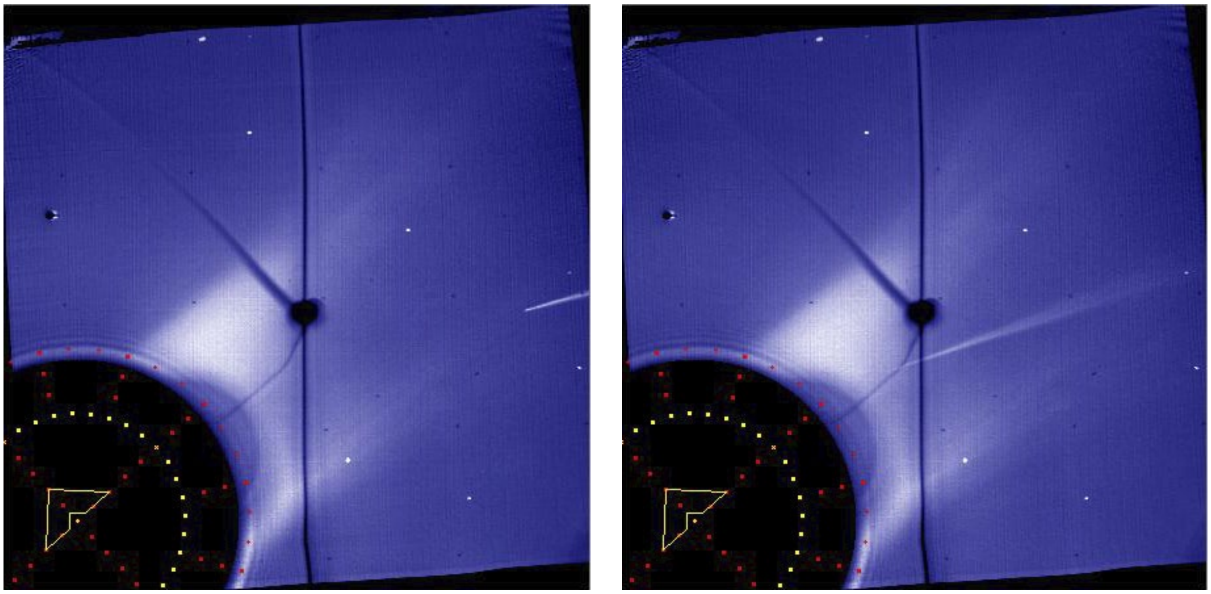
Any thought that the appearance of this SOLWIND comet was a unique phenomenon began to be dispelled in July 1982, when the NRL team detected images of two additional comets in SOLWIND images, one in January 1981, the other in July 1981. Both of these were also found to be Kreutz sungrazers, and both were fainter than the first one, with neither of them surviving perihelion passage. Over the next three years the NRL team detected three additional Kreutz sungrazing comets in SOLWIND images, the last of these appearing in July 1984. Then, on September 13, 1985, P78-1 was deliberately destroyed as part of an Anti-Satellite (ASAT) weapon test, although two of its instruments, including the SOLWIND coronagraph, were still operating. In more recent years a German amateur astronomer, Rainer Kracht, has detected four additional comets in archived SOLWIND data, with three of these being Kreutz sungrazers but with the fourth one (which appeared in September 1984) having a distinctly different orbit.



Astronaut George Nelson from the Space Shuttle Challenger approaches the Solar Maximum Mission (SMM) satellite on April 8, 1984. Courtesy NASA.

Fortunately, by the time of P78-1's destruction NASA's Solar Maximum Mission (SMM) satellite, which had been launched on February 14, 1980 but which had then suffered a major failure of its attitude-control system a few months later, had been repaired by astronauts aboard the Space Shuttle Challenger during a dramatic rescue-and-repair mission in April 1984. Among SMM's instruments was a coronagraph, and in July of that year SMM successfully took two images of the last SOLWIND sungrazer. Between 1987 and the time it entered Earth's atmosphere and burned up on December 2, 1989, SMM detected ten additional comets, all Kreutz sungrazers. None of these survived perihelion passage and none of them were observed from the ground, although the brightest of them – SMM 5, which appeared on October 11 and 12, 1988 – was bright enough, and appeared at the right time of the year for favorable viewing geometry, that I made a couple of attempts to view it after perihelion – without success, obviously.

These SOLWIND and SMM comet discoveries indicated that there is a population of small Kreutz sungrazers that had not been heretofore suspected. The joint NASA/ESA SOlar and Heliospheric Observatory (SOHO) mission launched in December 1995, which carries better coronagraphs than those carried by SOLWIND and SMM, has raised this to a new level, with approximately 3400 Kreutz sungrazers having now been detected. The two spacecraft of the Solar-TErrestrial RElations Observatory (STEREO) mission launched in October 2006 have also detected numerous Kreutz sungrazers. The SOHO sungrazers are discussed in a previous "Comet of the Week" presentation, and as already mentioned the entire remarkable "family" of Kreutz sungrazers is the subject of a future "Special Topics" presentation.

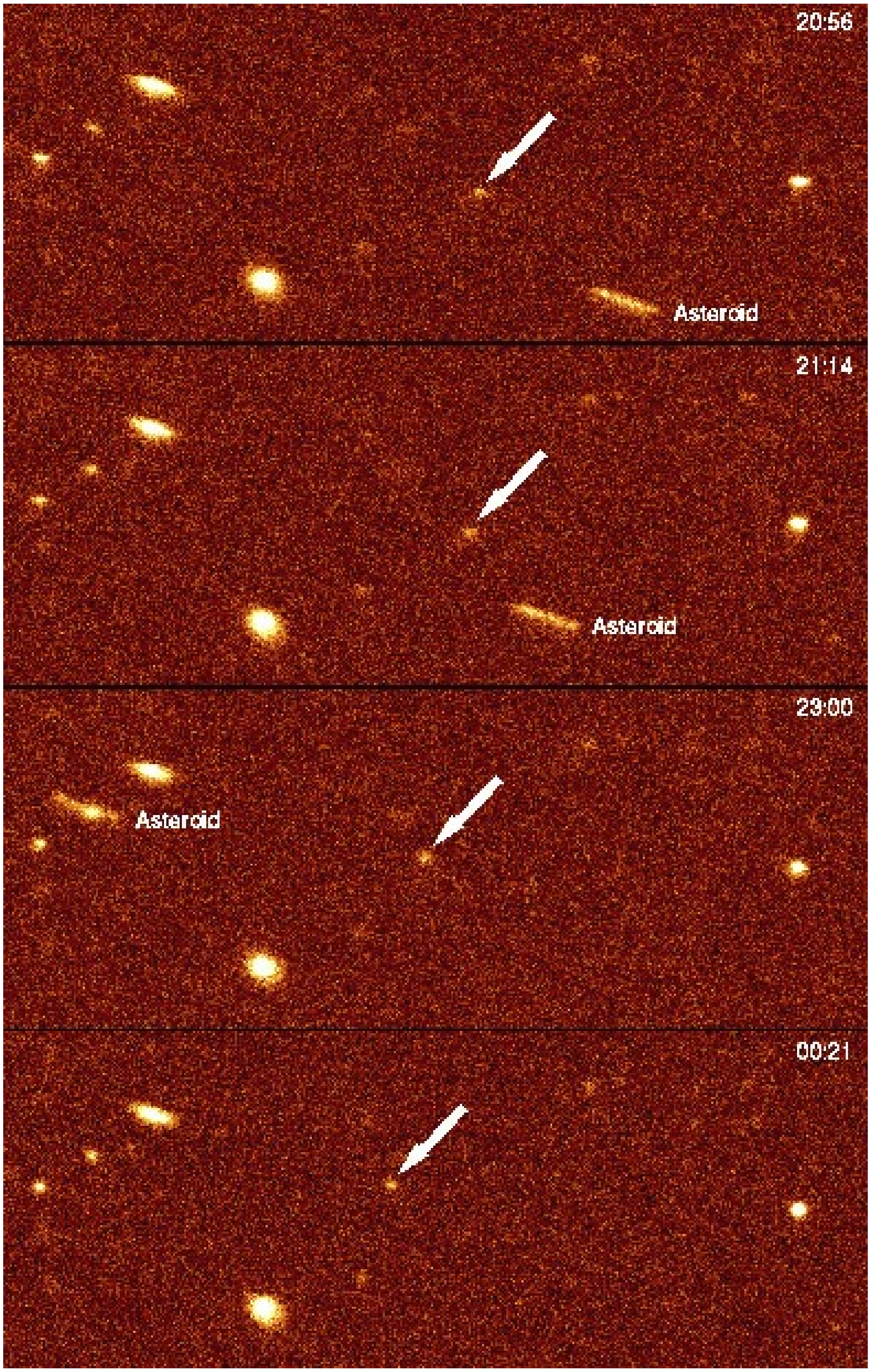


Images of the last SOLWIND Kreutz sungrazer (SOLWIND 5) taken by the coronagraph aboard SMM, July 28, 1984. Courtesy HAO/SMM C/P project team/NASA.

SPECIAL TOPIC: THE KUIPER BELT

Where the various comets that we see in our skies come from has long been a subject of high scientific interest. The Week 3 "Special Topics" presentation discussed how in the mid-20th Century the Dutch astronomer Jan Oort proposed the existence of the structure that we now call the "Oort Cloud" as being the source of the long-period comets. The Oort Cloud, however, does not adequately explain the large numbers of short-period comets, which tend to have low orbital inclinations, so these must come from another source. At right around the same time that Oort was proposing his ideas, an Irish engineer, Kenneth Edgeworth, proposed the existence of a disk-like structure of cometary bodies that began not too far beyond Neptune and extended out for perhaps a few hundred AU, and right around that same time the Dutch-American planetary scientist Gerard Kuiper independently proposed something similar. Kuiper made his proposal within the context of the overall formation of the solar system, and in his view the bodies within this disk were "leftovers" from the formation of the planets.

Kuiper's ideas essentially lay dormant for the next several decades. The idea of a population of objects in that part of the solar system was resurrected in the early 1980s by an astronomer from Uruguay, Julio Fernandez, and more vigorously later that decade by a trio of Canadian astronomers (Martin Duncan, Thomas Quinn, and Scott Tremaine), in at attempt to explain the origin of the low-inclination Jupiter-family comets. A series of mathematical calculations performed by the Canadian trio showed that this "Kuiper Belt" could account for the relatively large number of such objects that we see.

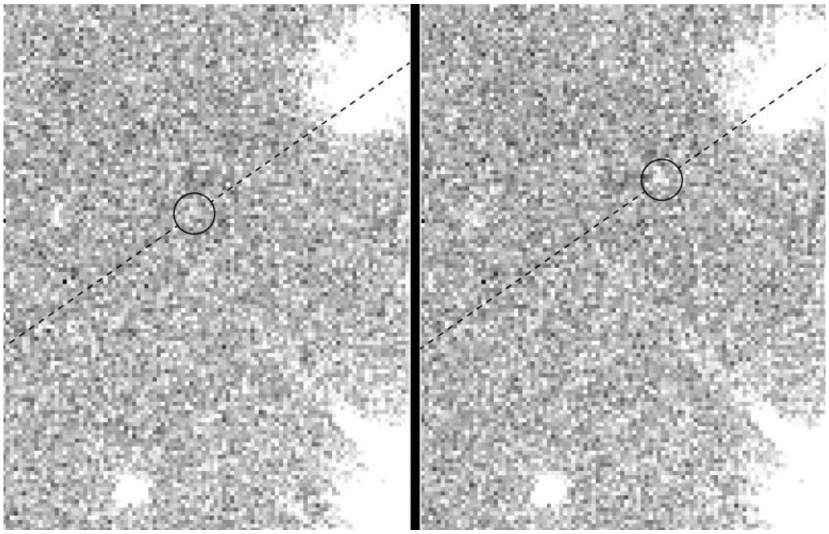


The discovery images of the Kuiper Belt object provisionally designated 1992 QB1, now known as (15760) Albion, taken August 30, 1992, with the 2.2-meter telescope at Mauna Kea Observatory in Hawaii. Courtesy David Jewitt.

By that time observational technology and techniques had improved to the point where searches for such objects was practical. For the next few years several astronomers engaged in search efforts for them, but initially these were all unsuccessful. Finally, on August

30, 1992, two American astronomers, David Jewitt and Jane Luu, discovered an extremely faint (23rd magnitude) very slow-moving object – provisionally designated 1992 QB1 – in CCD images taken with the 2.2-meter telescope at Mauna Kea Observatory in Hawaii. Due to its slow motion, orbital calculations were problematical for a while, but eventually it was established that 1992 QB1 is traveling in a near-circular low-inclination orbit at an average heliocentric distance of 44 AU and an orbital period of 290 years – right where the Kuiper Belt was predicted to be.

The question now was whether or not 1992 QB1 was a unique object, or if there might be additional objects located in that part of the solar system. That question began to be answered on March 28, 1993, when Jewitt and Luu discovered a second very faint, slow-moving object, 1993 FW, that has been found to be traveling in an orbit quite similar to that of 1992 QB1. In September 1993 Jewitt and Luu discovered two additional objects, 1993 RO and 1993 RP, and shortly afterward two more objects, 1993 SB and 1993 SC, were detected by a team of astronomers led by Iwan Williams using the 2.5-meter Isaac Newton Telescope at La Palma Observatory in the Canary Islands. Still more objects began to be discovered in 1994, and since then the discovery rate of these objects – sometimes called "Trans-Neptunian Objects," or TNOs – has accelerated. Today over 2400 TNOs have been discovered, and several of the longest-known ones with well-established orbits have been numbered and in some cases named as well. 1992 QB1 is now formally known as (15760) Albion, the name referring to the "island-dwelling primordial man" in the creation mythology of the early 19th-Century British poet William Blake.



Two images of a candidate Kuiper Belt object taken 1.75 hours apart on August 22, 1994, with the Hubble Space Telescope by Anita Cochran. Courtesy NASA.

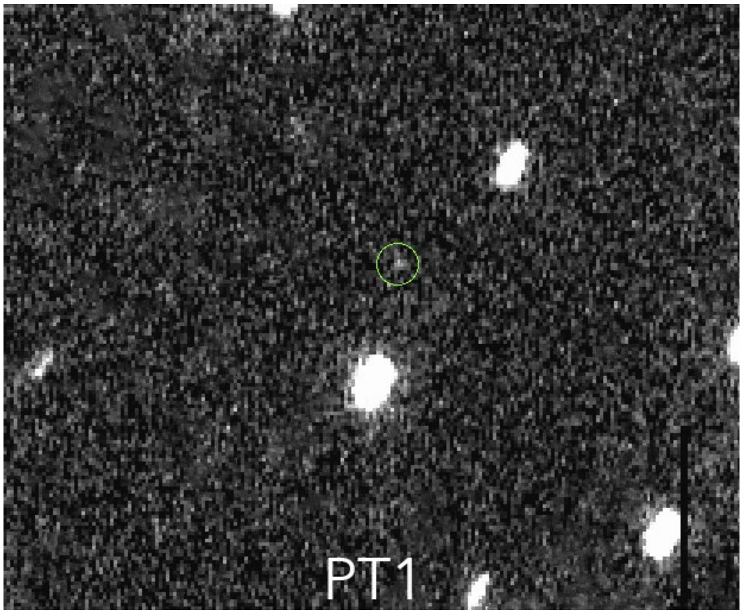
In physical terms Albion has been estimated as being roughly 150 to 200 km in diameter, and a significant percentage of the other TNOs that have been discovered are also likely within this same size range. Current estimates are that are as many as 100,000 such objects 100 km in diameter or larger within the Kuiper Belt. Meanwhile, in August 1994 a team of astronomers led by Anita Cochran at the University of Texas took a series of exposures with the Hubble Space Telescope of a small region of sky in the constellation Taurus and appear to have detected between 30 to 50 extremely faint objects – approximately 28th magnitude – with motions consistent with location in the Kuiper Belt. While there has been some controversy associated with these results, at face value they nevertheless suggest that down to an approximate size of 10 km there may be as many as 100 million objects within the Kuiper Belt.

Several of the TNOs that have been discovered thus far, including some of the early known ones, have been found to be traveling in moderate-eccentricity orbits with average heliocentric distances of 39 AU and orbital periods close to 250 years – the same situation that exists with Pluto. These objects, including Pluto, are in what is called a "2:3 resonance" with Neptune, i.e., they orbit the sun twice for every three orbits that Neptune makes, and as a result always remain in stable orbits far away from Neptune. Such objects are now often collectively referred to as "plutinos." Several Kuiper Belt objects have been found that are traveling in a 1:2 resonance with Neptune, i.e., orbiting the sun once for every two orbits that Neptune makes, their average heliocentric distances being close to 48 AU and their orbital periods being approximately 330 years. A handful of TNOs have been found which appear to be orbiting in other orbital resonances with Neptune, for example 3:4 and 3:5. On the other hand, a fairly large number of TNOs, including Albion, are not in any particular resonance with Neptune, and these objects are sometimes collectively referred to as "cubewanos" (a name taken from Albion's provisional designation).

A non-trivial percentage of TNO's, beginning with the first-known such object – (15874) 1996 TL66, discovered in October 1996 – are traveling in larger-eccentricity orbits more reminiscent of comets with orbital periods of several centuries (eccentricity of 0.58 and orbital period of 750 years in this specific case). Such objects are part of what is now called the "scattered disk," and due to their average large distances

they are at present only detectable when they are near perihelion. Somewhat over 200 scattered disk objects have been discovered thus far, but their true population is probably at least similar to that of the more "traditional" Kuiper Belt.

Due to their large distance and extreme faintness, it is difficult to perform much in the way of physical studies of TNOs, although this is helped to some extent by the fact that several dozen of them have been found to be accompanied by moons, thus allowing for determinations of their mass via application of Newton's Law of Universal Gravitation and Kepler's Third Law. (The topic of moons around these objects, and around "small bodies" in general, is the subject of next week's "Special Topics" presentation.) What studies that have been conducted thus far suggest that there is a fairly wide range of composition ingredients among TNOs, although ices, including water ice, appear to be a fairly common component, as well as some forms of rocky material. A significant percentage of them, although not all, appear to be reddish in color, this most likely being due to the presence of tholins – organic molecules created by cosmic ray bombardment of ices, as described in a previous "Special Topics" presentation – on their surfaces. It is conceivable that some of the observed compositional differences can be explained by impacts that have "churned up" varying amounts of subsurface material, although this probably does not account for all the differences. In any event, although the structure of the Kuiper Belt is not quite consistent with what he proposed, Kuiper's suggestion that the population of this region is made up of "leftovers" from the planet formation process appears to be valid.

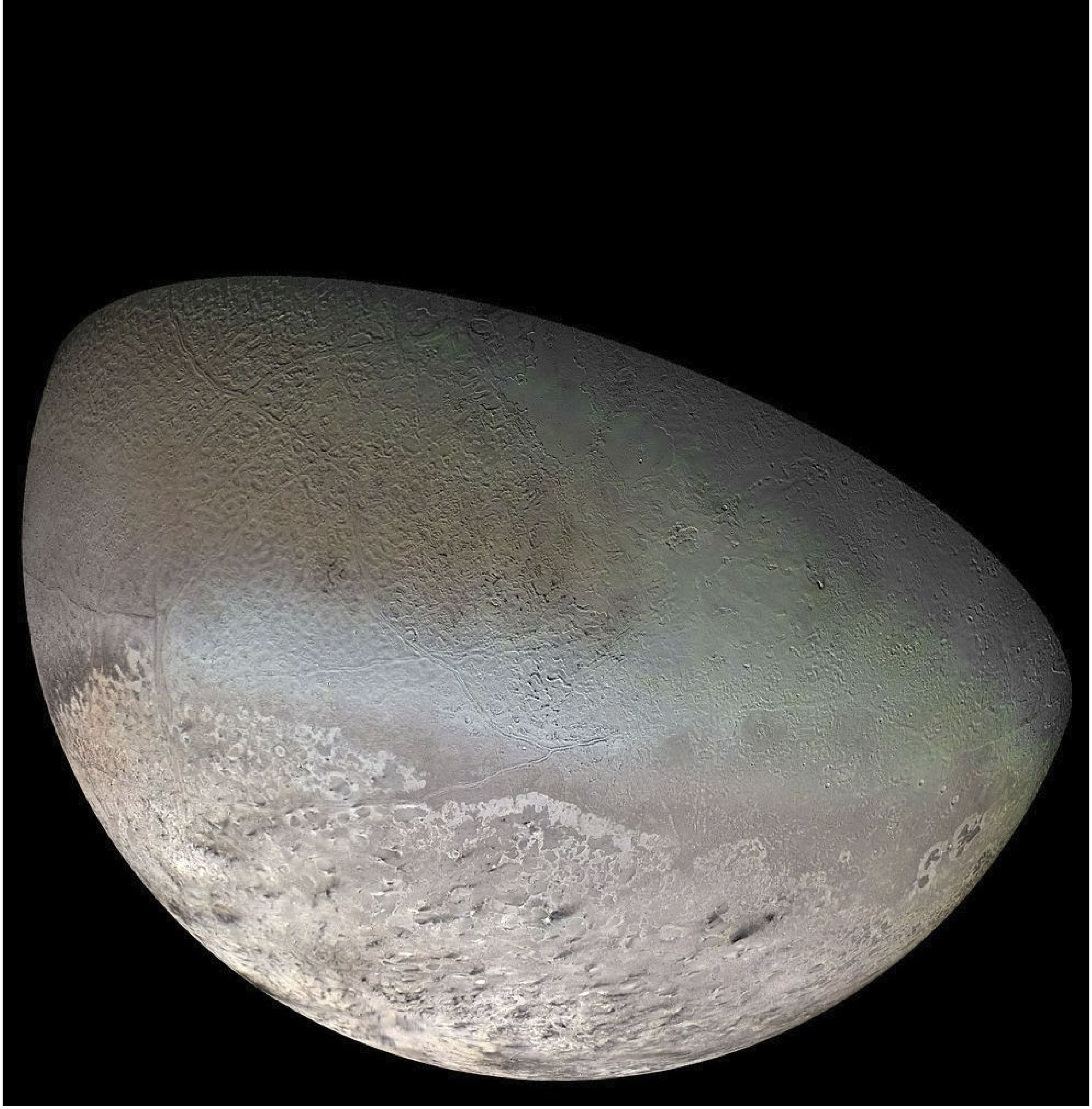


The Kuiper Belt object (486958) 2014 Arrokoth. Above: One of the discovery images, taken June 26, 2014 by Marc Buie with the Hubble Space Telescope. Left page: Image by NASA's New Horizons spacecraft on January 1, 2019. "Maryland" is the large crater on the right side of the smaller component, "Thule." Both images courtesy NASA.

The one object that has been studied up close is (486958) Arrokoth. It was discovered on June 26, 2014 by a team of astronomers led by Marc Buie who were utilizing the Hubble Space Telescope to search for candidate Kuiper Belt objects that could be visited by NASA's New Horizons mission following its flyby of Pluto in July 2015; it was one of three candidates so identified. Arrokoth orbits the sun in a near-circular orbit at an average heliocentric distance of 44.6 AU, and, with an apparent brightness of about 27th magnitude, is roughly 36 km by 10 km in its longest and shortest dimensions.

New Horizons passed 3500 km from Arrokoth on January 1, 2019. The images returned from New Horizons show it to be what is called a "contact binary" – among the objects discussed in next week's "Special Topics" presentation – with a larger object, "Ultima," and a smaller object "Thule" (these names coming from the nickname "Ultima Thule" originally given to this object), stuck together, with a ring of bright surface material around their junction. (One large apparent impact crater, nicknamed "Maryland," is visible on "Thule.") The overall surface color is quite reddish, indicating the presence of tholins, and analyses suggest an overall composition primarily of ices and other frozen volatiles. The download of data from the Arrokoth encounter has been ongoing ever since the event itself, and meanwhile it is possible that New Horizons might be directed towards an encounter with an as-yet-unidentified more distant Kuiper Belt object later this decade.

The various objects in the "traditional" Kuiper Belt, including those in both resonant and non-resonant orbits, appear to be gravitationally stable, and thus perhaps are not significant contributors to the population of short-period comets in the inner solar system. Rather, it is the scattered disk objects that are the most likely source of these objects, with a steady progression of scattered disk objects to centaurs – discussed in a previous "Special Topics" presentation – to short-period comets. As for how the scattered disk objects got there in the first place, gravitational scattering by the larger planets during the early days of the solar system, including Neptune which appears to have been located farther from the sun during that era than it is now, is most likely responsible. Incidentally, it seems likely that Neptune's large moon Triton, which orbits in a near-circular but somewhat inclined retrograde orbit, is a "captured" Kuiper Belt object.

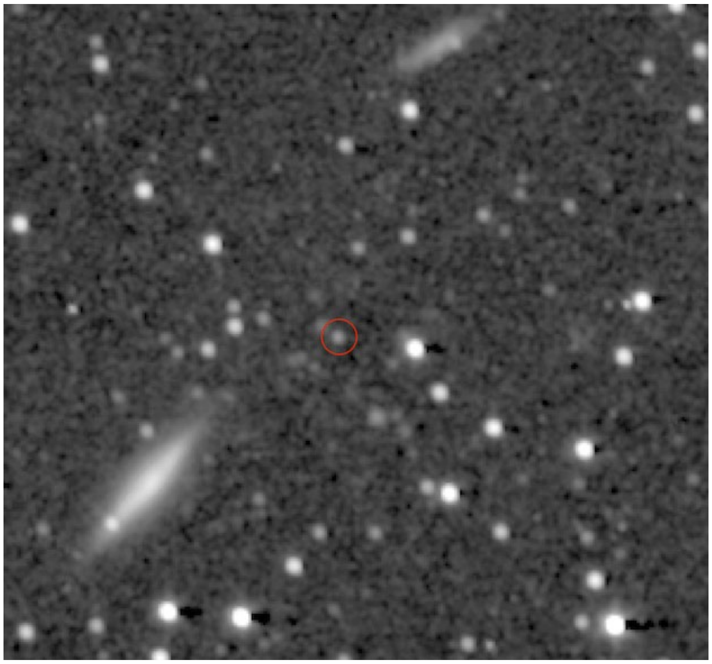


Neptune's large moon Triton, as imaged by NASA's Voyager 2 spacecraft on August 25, 1989. Triton is likely a "captured" Kuiper Belt object. Courtesy NASA/JPL/USGS.

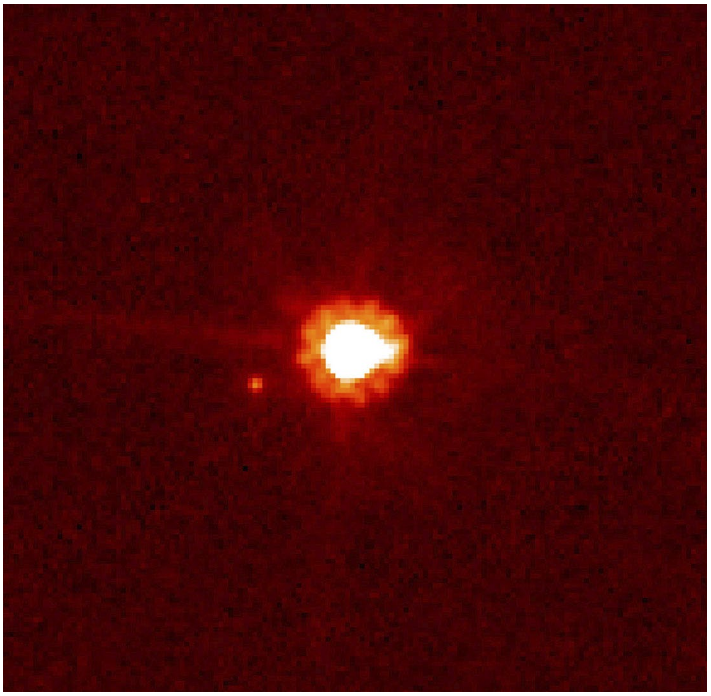
Initially, most of the discovered TNOs were roughly the same size as Albion. However, in November 2000 Robert McMillan with the Spacewatch program in Arizona discovered the TNO now known as (20000) Varuna, which has an approximate diameter of 680 km, approximately ¾ the diameter of (1) Ceres. Then, in June 2002 Chad Trujillo and Michael Brown at Palomar Observatory in California discovered the TNO now known as (50000) Quaoar, which has an approximate diameter of 1100 km, roughly half that of Pluto. Since Pluto is in this same region of the solar system it seemed entirely conceivable that, at some point, Kuiper Belt objects might be discovered that are as large as, or conceivably even larger than, Pluto.

This finally happened in 2005, when on July 29, Brown and his team announced the discovery of three approximate Pluto-sized Kuiper Belt objects, now known as (136108) Haumea, (136199) Eris, and (136472) Makemake. (Haumea and Eris had actually been discovered in 2003 but not yet announced, and Haumea was also independently discovered by a Spanish team led by Jose Ortiz. All three of these objects have at least one moon – Haumea has at least two and also an accompanying ring – and

Haumea is rather strongly ellipsoidal in shape due to a rapid rotation.) Eris – which is a scattered disk object with an eccentricity of 0.44, an inclination of 44 degrees, an orbital period of 558 years and a present heliocentric distance of 96.0 AU with a perihelion passage at a distance of 38 AU taking place in 2257 – was originally thought to be slightly larger than Pluto, but with a rough measured diameter of 2326 km (as opposed to 2377 km for Pluto as determined by New Horizons) is now known to be slightly smaller, although the presence of its moon Dysnomia allows its mass to be determined as being 27% more than that of Pluto.



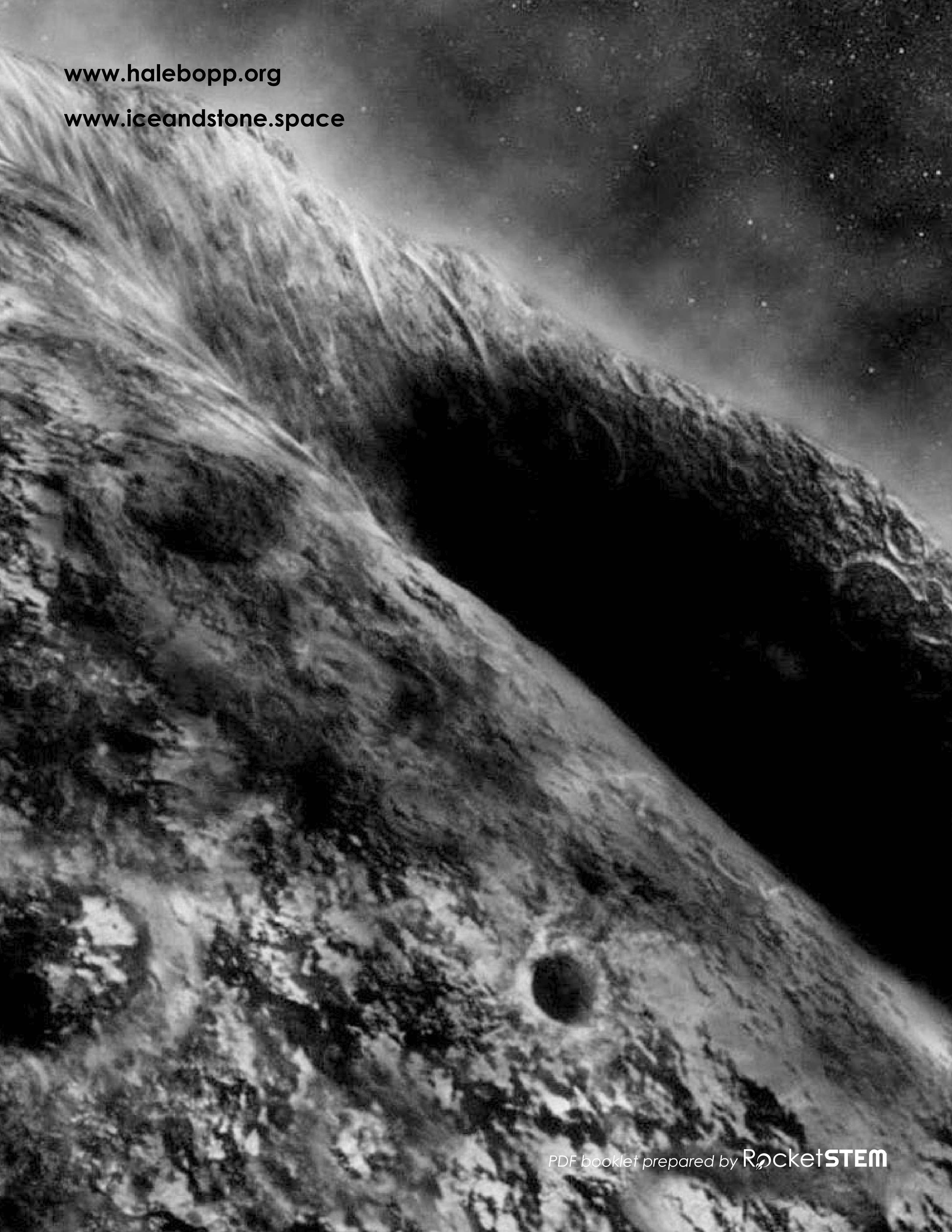
Two of the largest known Kuiper Belt objects. Above: (50000) Quaoar, as imaged distantly by the New Horizons spacecraft on July 13, 2016. Courtesy NASA/JHUAPL/Southwest Research Institute. Below: (136199) Eris and its moon Dysnomia, as imaged by the Hubble Space Telescope on August 30, 2006. Courtesy NASA/ESA/Michael Brown.



The discovery of these objects, Eris in particular, brought matters to a head as far as what is and what is not a "planet." If Pluto is a "planet" than Eris should also be one, and since Haumea and Makemake are only slightly smaller, valid arguments can be made for including them as "planets" as well. However, there appears to be a gradual continuum all the way down, and where to draw the line between what is and what is not a "planet" quickly becomes a completely arbitrary exercise. It was considerations like these that led the International Astronomical Union to adopt its formal designation of "planet" at its General Assembly in Prague, Czech Republic, in August 2006 and to create a new category of object, "dwarf planet," that at present includes Pluto, Eris, Haumea, and Makemake, as well as the main-belt asteroid (1) Ceres. As I argued in Pluto's "Special Topics" presentation, whatever arbitrary label we might append to any object does not in any way detract from its importance, for these are all unique and exciting worlds, worthy of study in their own right. Such a viewpoint also indicates that Pluto was the first-known Kuiper Belt object (although obviously unrecognized as such at the time) – that is, unless one also wishes to include Triton (discovered by British astronomer William Lassell in 1846, and 14% larger than Pluto) as a "captured" Kuiper Belt object.

It is entirely possible that we will discover additional large worlds among the TNOs as our search efforts continue. Meanwhile, the Kuiper Belt and the scattered disk are not the final world on the population of objects in the solar system beyond Neptune; beginning with the discovery of the object now known as (90377) Sedna in 2003 we now know that there are objects in the far outer solar system as well. These objects are discussed in a future "Special Topics" presentation.

While we now know that there is no such thing as a "typical" planetary system, it at least seems likely that the processes by which planetary systems form essentially remain the same from one system to another. Thus, structures akin to the Kuiper Belt would be expected to exist around other stars, and, indeed, excess infrared radiation indicative of dust, as well as debris disks, have been detected around various stars for the past few decades. Some of these are located at distances from their parent stars that are comparable to our solar system's Kuiper Belt and may well represent a similar type of structure. These are discussed in a future "Special Topics" presentation.



www.halebopp.org

www.iceandstone.space

PDF booklet prepared by RocketSTEM