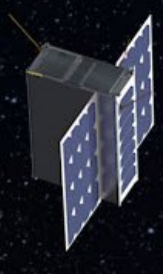
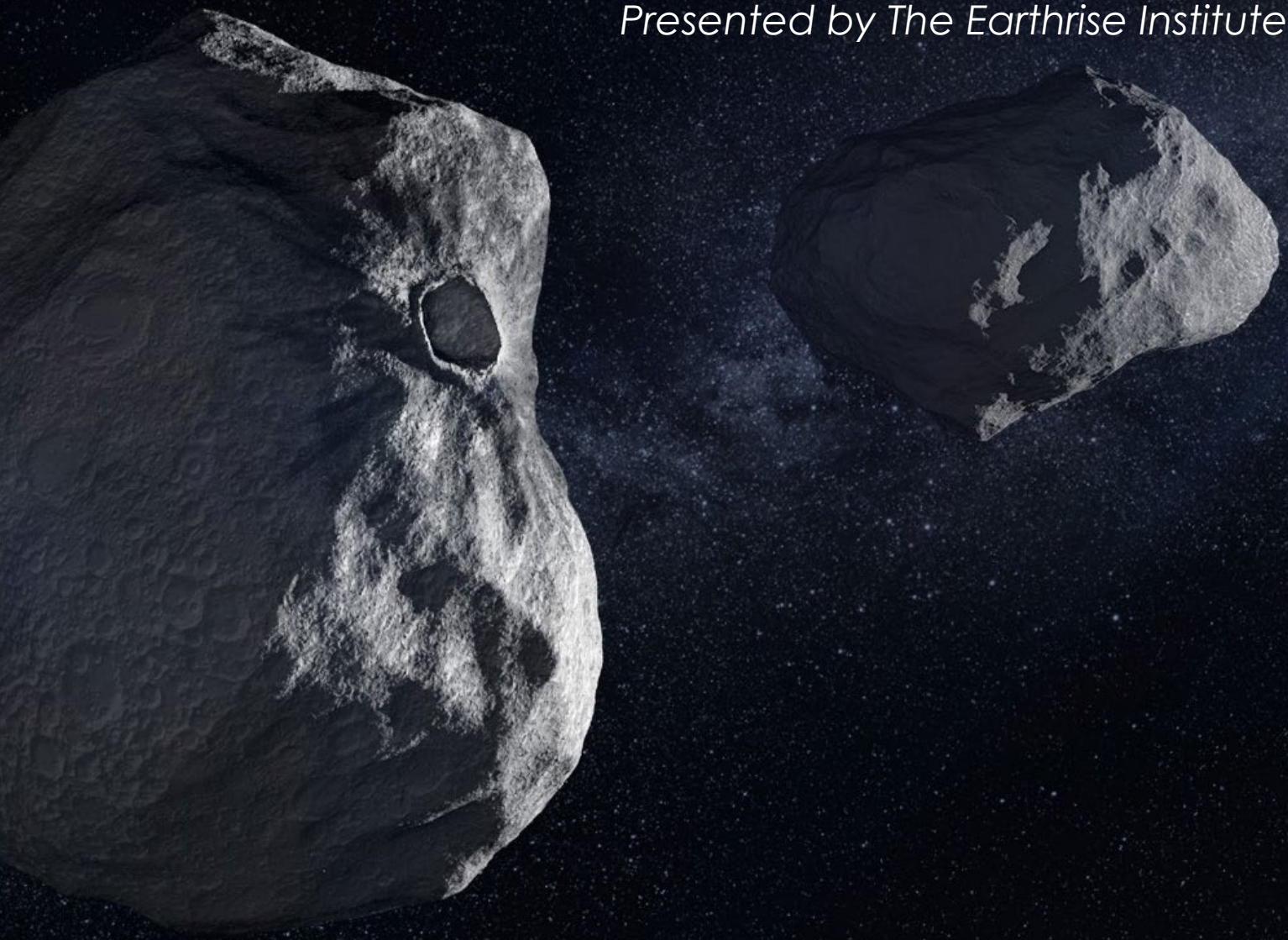


ICE & STONE 2020

WEEK 24: JUNE 7-13

Presented by The Earthrise Institute



#24

Authored by Alan Hale

THIS WEEK IN HISTORY

JUNE 7 | 8 | 9 | 10 | 11 | 12 | 13

JUNE 7, 2013: A team led by Dutch astronomer Nienke van der Marel announces their discovery of a planet-forming – and comet-forming – disk of material surrounding the young star Oph-IRS 48 in the constellation Ophiuchus, using data obtained with the Atacama Large Millimeter/submillimeter Array (ALMA) telescope in Chile. An ALMA image of this disk is featured in a previous "Special Topics" presentation.

JUNE 7, 2020: The Daytime Arietid meteor shower will be at its peak. This is the strongest of the daytime meteor showers, with a peak rate of 30 to 60 meteors per hour, but since it is a daytime shower primarily detectable via radar, visual observations are very limited. Such observations may nevertheless be possible, although the moon will be full on June 5.

7 | JUNE 8 | 9 | 10 | 11 | 12 | 13

JUNE 8, 1967: Elizabeth Roemer at Catalina Observatory in Arizona photographs a faint suspect for Comet 9P/Tempel 1, which had been lost since 1879. Since this suspect appeared on only a single photograph, it could not be confirmed until the comet was successfully recovered at the subsequent return in 1972. Comet 9P/Tempel 1 was the destination of the Deep Impact mission and subsequently the extended Stardust mission, and is a future "Comet of the Week."

7 | 8 | JUNE 9 | 10 | 11 | 12 | 13

JUNE 9, 1988: Pluto occults a 12th-magnitude star in Virgo. During the occultation the star disappeared and reappeared gradually, providing the first direct evidence for an atmosphere around Pluto. Pluto is the subject of a future "Special Topics" presentation.

JUNE 9, 2020: The Apollo-type asteroid (144411) 2004 EW9 will pass 0.090 AU from Earth. Prior to this approach the asteroid will be accessible from the southern hemisphere at 15th magnitude, but afterwards will fade rapidly as it travels interior to Earth's orbit.

7 | 8 | 9 | JUNE 10 | 11 | 12 | 13

JUNE 10, 1982: The International Sun-Earth Explorer 3 (ISEE-3) spacecraft, which had been stationed at the L1 Lagrangian point sunward of Earth since its launch in 1978, is moved away from L1 to begin a series of lunar flybys that would eventually send it (under the name International Cometary Explorer, or ICE) to Comet 21P/Giacobini-Zinner in 1985, the first spacecraft to encounter a comet. ICE is discussed in a future "Special Topics" presentation, and Comet 21P/Giacobini-Zinner is a future "Comet of the Week."

JUNE 10, 2019: The Zwicky Transient Facility (ZTF) survey program based in California discovers the Atira-type asteroid 2019 LF6. This had the smallest orbit of any asteroid known at that time, with a semi-major axis of 0.56 AU, an orbital period of 151 days, and an aphelion distance of 0.79 AU (slightly beyond Venus' orbit). However, the Atita-type asteroid 2020 AV2 (discovered early this year), which is the first-known asteroid with an orbit entirely interior to that of Venus, has an identical orbital period. 2020 AV2 is discussed as a special addendum to an earlier "Special Topics" presentation.

7 8 9 10 11 JUNE 12 13

JUNE 12, 1861: Comet Tebbutt 1861 II (new style: C/1861 J1) passes through perihelion at a heliocentric distance of 0.822 AU. Later that month it passed close to Earth and briefly became one of the brightest comets of the 19th Century; it is a future "Comet of the Week."

JUNE 12, 1999: "Comet" C/1999 J6, discovered in images taken with the LASCO coronagraph aboard the SOlar and Heliospheric Observatory (SOHO) but not noticed until a year later, passes just 0.013 AU from Earth, which in theory makes it the closest cometary approach to Earth in history. However, although this object has been detected at two subsequent returns (both times in LASCO images), it has never been detected from the ground, and its true physical nature remains unknown. It (along with a similar SOHO-discovered "comet") is discussed in a previous "Special Topics" presentation.

7 8 9 10 11 12 JUNE 13

JUNE 13, 1968: The Haystack Radio Telescope in Massachusetts successfully detects radar beams bounced back from the near-Earth asteroid (1566) Icarus during that object's close passage by Earth, and NASA's Deep Space Network tracking antenna in Goldstone, California does so one day later. These were the first successful radar detections of a solar system "small body."

JUNE 13, 2006: NASA's New Horizons mission, which had been launched back in January, flies by the small main-belt asteroid (132524) APL while en route to Jupiter for a gravity assist for its journey to Pluto. The New Horizons mission is discussed in future "Special Topics" presentations.

JUNE 13, 2010: JAXA's Hayabusa mission returns to Earth following an eventful journey to and from the near-Earth asteroid (25143) Itokawa. Hayabusa successfully collected a handful of soil samples from Itokawa, however upon leaving there contact with Hayabusa was lost for several months before successfully being re-established, which forced a three-year delay in its eventual return. These were the first soil samples from an asteroid to be brought to Earth. Hayabusa and other missions to asteroids are discussed in a future "Special Topics" presentation.

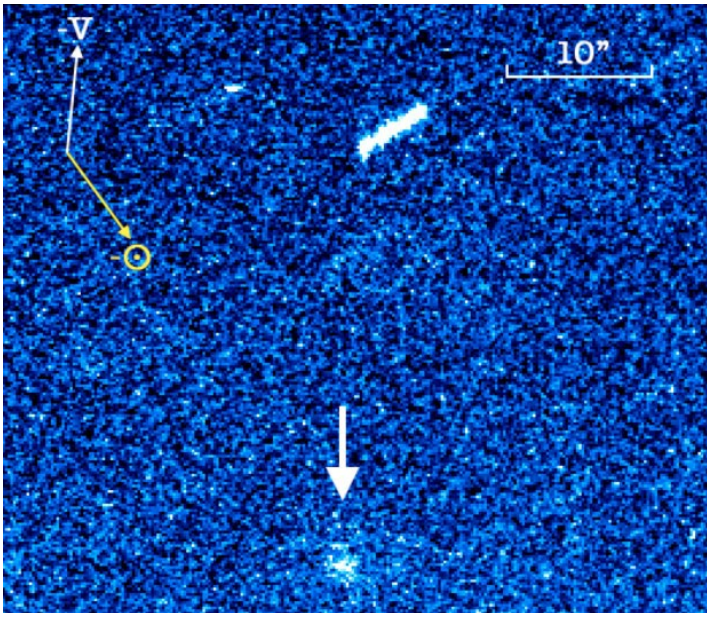
JUNE 13, 2043: The near-Earth asteroid (1566) Icarus will pass 0.059 AU from Earth. This is the next time that this well-known Earth-approaching asteroid will come close to our home planet.

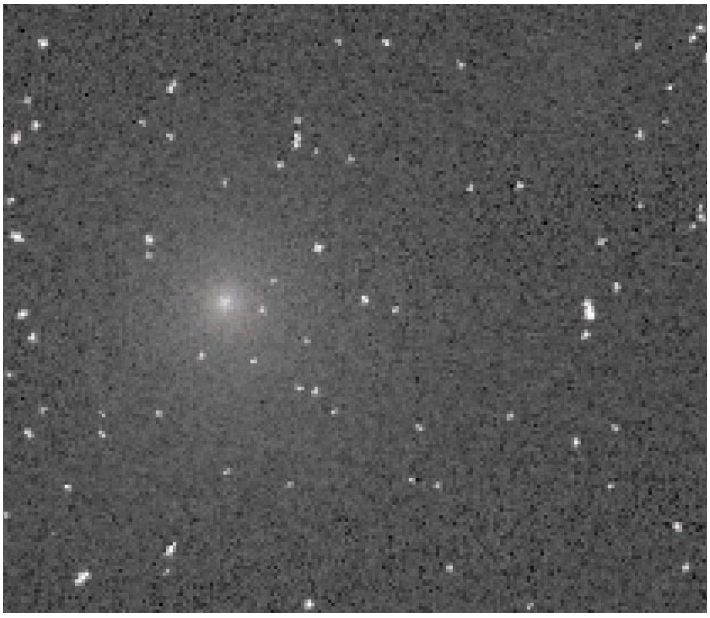
COVER IMAGE CREDIT:

Front and back cover: This artist's conception shows ESA's proposed Hera Mission to the Didymos binary asteroid system. Courtesy of ESA/ScienceOffice.org.

COMET OF THE WEEK: PANSTARRS C/2017 K2

Perihelion: 2020 December 19.67, q = 1.797 AU





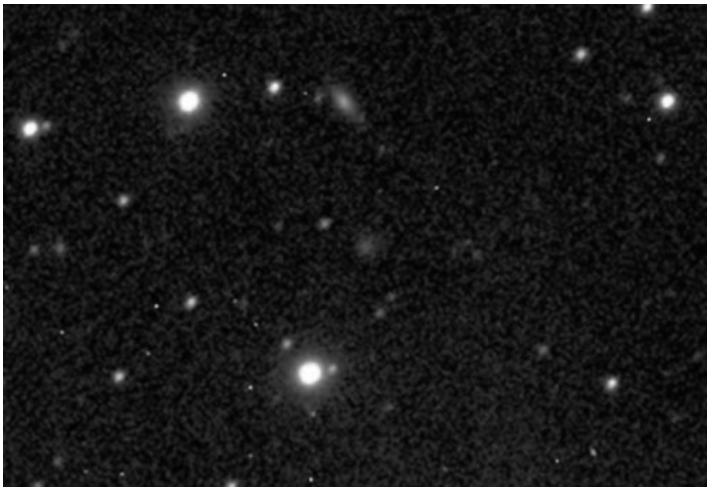
LEFT: Pre-discovery image of Comet PANSTARRS taken with the Canada-France-Hawaii Telescope at Mauna Kea on May 12, 2013, when its heliocentric distance was 23.7 AU. From the paper by Jewitt et al. (2017). RIGHT: Hubble Space Telescope image of Comet PANSTARRS taken on June 27, 2017, when its heliocentric distance was 15.9 AU. Courtesy NASA.

I've hinted in some of the earlier presentations of "Ice and Stone 2020" that, for the past few years, we have been in a slow period when it comes to bright comets. Indeed, for "Great Comets" – discussed in a previous "Special Topics" presentation – the most recent one appeared in 2011, and the most recent one that was easily visible from the northern hemisphere appeared as long ago as 1997. We've been teased a couple of times in the very recent past, but Comet ATLAS C/2019 Y4 (an earlier "Comet of the Week") disintegrated as it approached perihelion, and while it was never expected to become "Great," Comet SWAN C/2020 F8 (discussed in that same presentation) apparently did likewise. So far, Comet NEOWISE C/2020 F3 seems to be brightening normally, but we'll have to wait and see what happens next month.

Intrinsically, this week's "Comet of the Week" is one of the brightest ever detected – its intrinsic brightness being comparable to that of Comet Hale-Bopp C/1995 O1 – and while it certainly possesses the potential to become a bright, perhaps even conspicuous, naked-eye object around the time of its perihelion passage, its somewhat large perihelion distance, combined with the fact that it remains far from Earth and will be visible only under mediocre viewing geometry, will likely keep it from becoming "Great." Furthermore, since it will be accessible only from the southern hemisphere for almost a full year around the time of perihelion, as far as observers in the northern hemisphere are concerned any potential it might have for becoming conspicuous is quite limited.

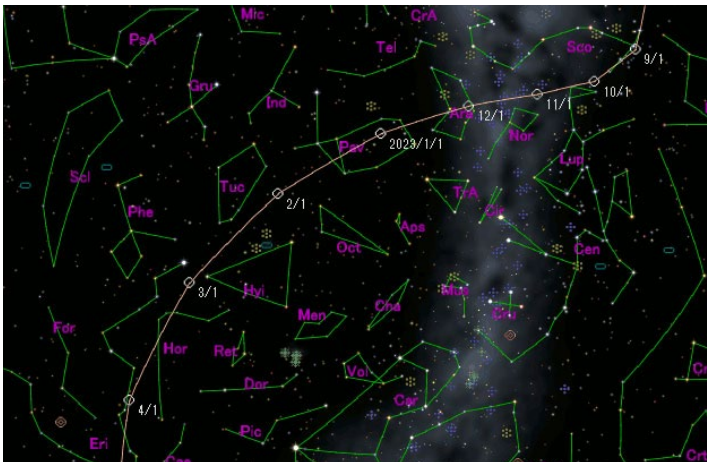
At the time of its discovery by the Pan-STARRS program based in Hawaii on May 21, 2017, the comet was about magnitude 19.5, and despite being located at a heliocentric distance of 16.1 AU was already clearly active. Researchers later identified images of it on exposures taken with the Canada-France-Hawaii Telescope at Mauna Kea as far back as May 12, 2013, at which time it was located 23.7 AU from the sun – the second-largest heliocentric distance at which any long-period comet has ever been detected; it was about magnitude 22.5 but was still showing activity even at that distance. Since this is far too large a distance for the sublimation of water ice, researchers have concluded that the activity was driven by sublimation of substances like carbon dioxide, carbon monoxide, and molecular oxygen and nitrogen.

Traveling in an orbit almost perpendicular to the ecliptic (inclination 87.5 degrees), Comet PANSTARRS has brightened steadily ever since its discovery as it has approached the inner solar system, and presently is around 15th to 16th magnitude. It is currently at opposition at a heliocentric distance of 8.9 AU, and located within the "head" of the constellation Draco. It travels slowly southward over the coming months, and



Images of Comet PANSTARRS I've taken with the Las Cumbres Observatory network that illustrate its development over the past two years. Left: Image taken from the LCO facility at McDonald Observatory in Texas on March 6, 2018, when the comet's heliocentric distance was 14.4 AU. It is the small diffuse object in the center. Right: Image taken from the LCO facility at Teide Observatory in the Canary Islands on May 15, 2020, when the comet's heliocentric distance was 9.2 AU. It is just to the lower left of center.

will be in conjunction with the sun – 59 degrees north of it – in mid-December. A year from now it is again at opposition, when its heliocentric distance will be 6.1 AU and it will be located 10 degrees south of its current location; by then it may be close to 13th magnitude and thus amenable to visual observations. One year later, i.e., in mid-June 2022, it will once again be near opposition, at a heliocentric distance of 2.9 AU and located in northern Ophiuchus; by then it should be bright enough to detect with binoculars and perhaps may even be close to naked-eye visibility.

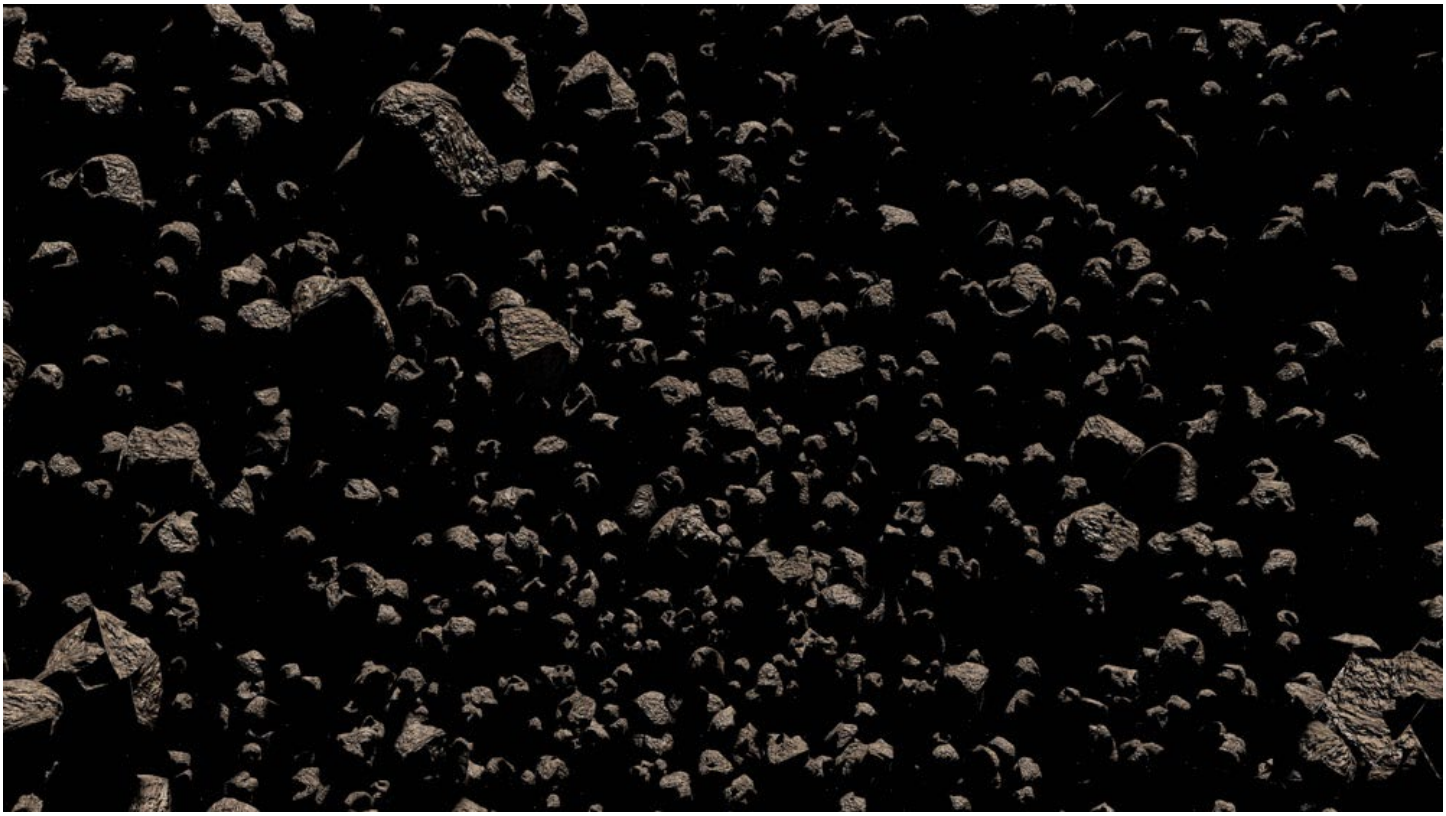


Path of Comet PANSTARRS through the southern constellations between September 2022 and April 2023. Courtesy Seiichi Yoshida.

After this, Comet PANSTARRS travels southward more rapidly, becoming inaccessible from northern temperate latitudes by the end of September and entering southern circumpolar skies in mid-December. At the time of perihelion is in conjunction with the sun – 38 degrees south of it – and is located on the far side of the sun from Earth. It reaches a peak southerly declination of -71 degrees shortly before the end of January 2023, and is still in southern circumpolar skies when it is nearest Earth (2.23 AU) in mid-February. Although it continues traveling northward it remains at a relatively small elongation south of the sun for the next several months, and is again in conjunction with the sun – 37 degrees south of it – in mid-June. During August it emerges into the morning sky and once again becomes accessible from the northern hemisphere, and will be at opposition shortly after mid-December when it will be located a few degrees east of the Orion Nebula M42; during the first few days of January 2024 it travels northwestward parallel to the stars of Orion's Belt about 1½ degrees south of that prominent stellar pattern. Visual observations may be possible for a few more months as it travels northward through the western evening sky and fades as it recedes from the earth and sun.

As is always the case with inbound long-period comets, any forecasts as to its brightness should be taken cautiously. The comet appears to be a "new" one making its first visit to the inner solar system from the Oort Cloud, and as discussed in a previous "Special Topics" presentation such objects tend to under-perform compared to what their earlier brightnesses might suggest. The fact that Comet PANSTARRS appears to be quite bright intrinsically and was active at such large heliocentric distances works in its favor, but its rather large perihelion distance, its remaining far from Earth, and its poor geometric viewing conditions around the time of perihelion work against it. The comet should certainly reach naked-eye brightness, perhaps 5th magnitude, and could become somewhat brighter than that; 3rd magnitude perhaps is reasonable, and while I would consider a peak brightness of 1st magnitude as unlikely, it is not out of the question. As I stated at the outset, though, I doubt that this will become a "Great Comet," although I suppose one never knows. We will just have to wait and see what the comet does.

SPECIAL TOPIC: "SMALL BODIES" IN CULTURE AND LITERATURE



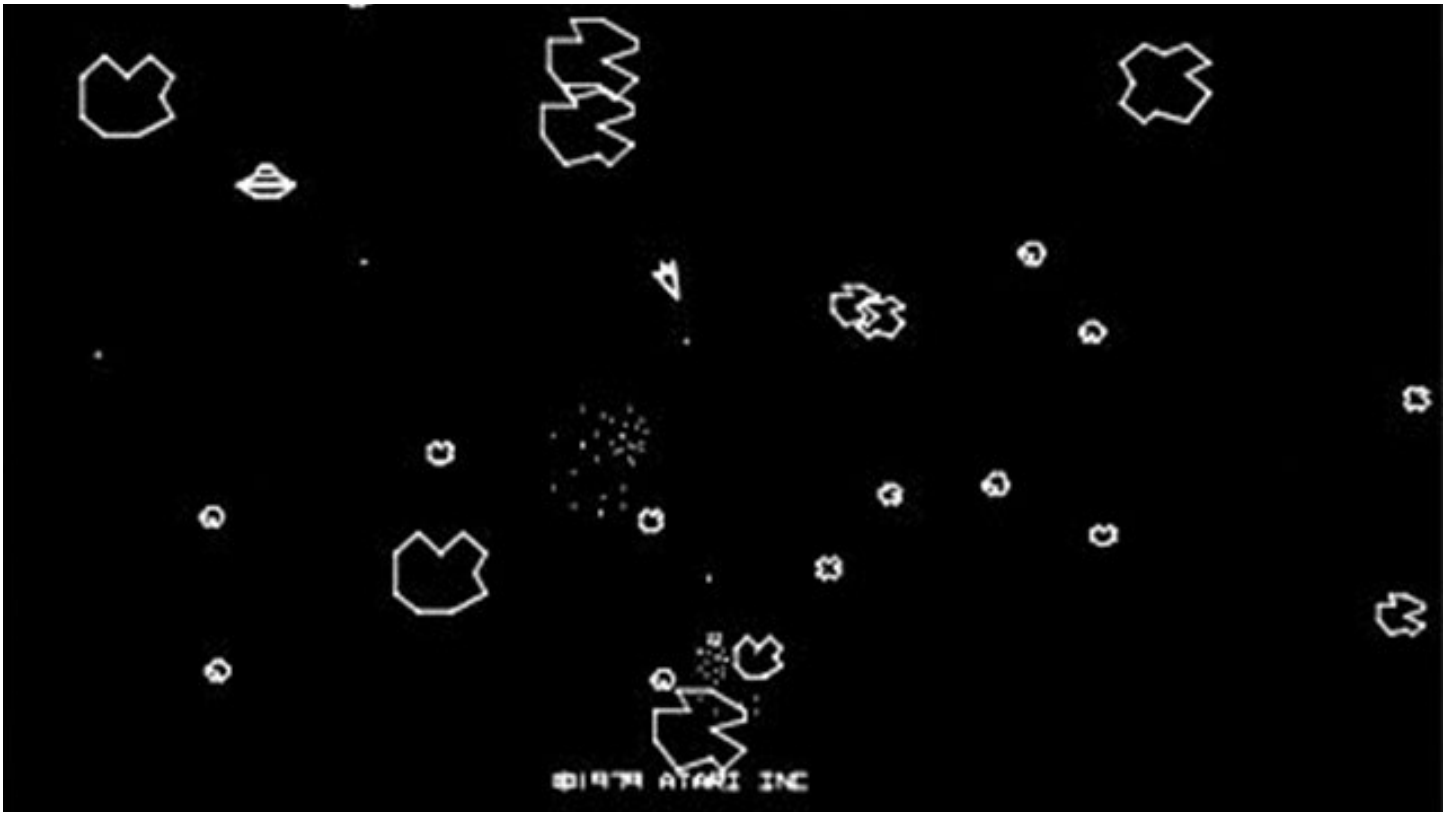
A field of asteroids, as often erroneously depicted in movies and television programs.

Although they may not be as big a presence in our overall human culture and literature as the moon and the other planets of our solar system are, the "small bodies" of our solar system are nevertheless present. There a number of misperceptions about them, perhaps more so than there are for the planets.

Consider, for example, the way that the main asteroid belt – and similar constructs in other planetary systems – are portrayed in fiction. Almost every depiction of asteroids – including the Atari video game "Asteroids" that was a very popular arcade game during the 1980s and which I was quite fond of playing at the time – portrayed the realm of asteroids as being a congested region full of ominous threatening objects that took a great deal of skill to navigate through without hitting one (or being hit by one). In reality, the volume of space that makes up the main asteroid belt is so large – 75 to 100 cubic A.U. or more – that the average distance between asteroids is on the order of several million km (15 to 20 lunar distances).

Indeed, the first spacecraft missions to the outer planets that traversed the asteroid belt – Pioneers 10 and 11 during the mid-1970s, and Voyagers 1 and 2 during the latter part of that decade – did so without ever encountering any asteroids while en route. Those spacecraft missions that have encountered asteroids since then – and which are discussed in a future "Special Topics" presentation – did so as a deliberate intent on the part of the mission planners. In practice, what is done nowadays is that when such a mission is planned, planners will look to see if there are any asteroids that might be near the expected trajectory, and if there are any such objects that can be visited without significantly affecting the overall mission timeline then such an encounter will be incorporated into the mission's itinerary.

Bright comets have often been portrayed in art and literature, this in no small part being due to the long-time fear that they were omens of disaster or some other sort of divine messenger, and I discussed several such examples in a previous "Special Topics" presentation. Comet 1P/Halley, in particular, due both to its regular appearances throughout human history and its high brightness during those appearances, has often been featured in the art and literature



Display of the 1980s Atari video game "Asteroids."

of its respective times, as I discuss in the "Special Topics" presentation devoted to that object; the more prominent examples include its depiction on the Bayeux Tapestry commemorating the Battle of Hastings and its depiction in the "Adoration of the Magi" fresco created by Italian artist Giotto di Bondone.

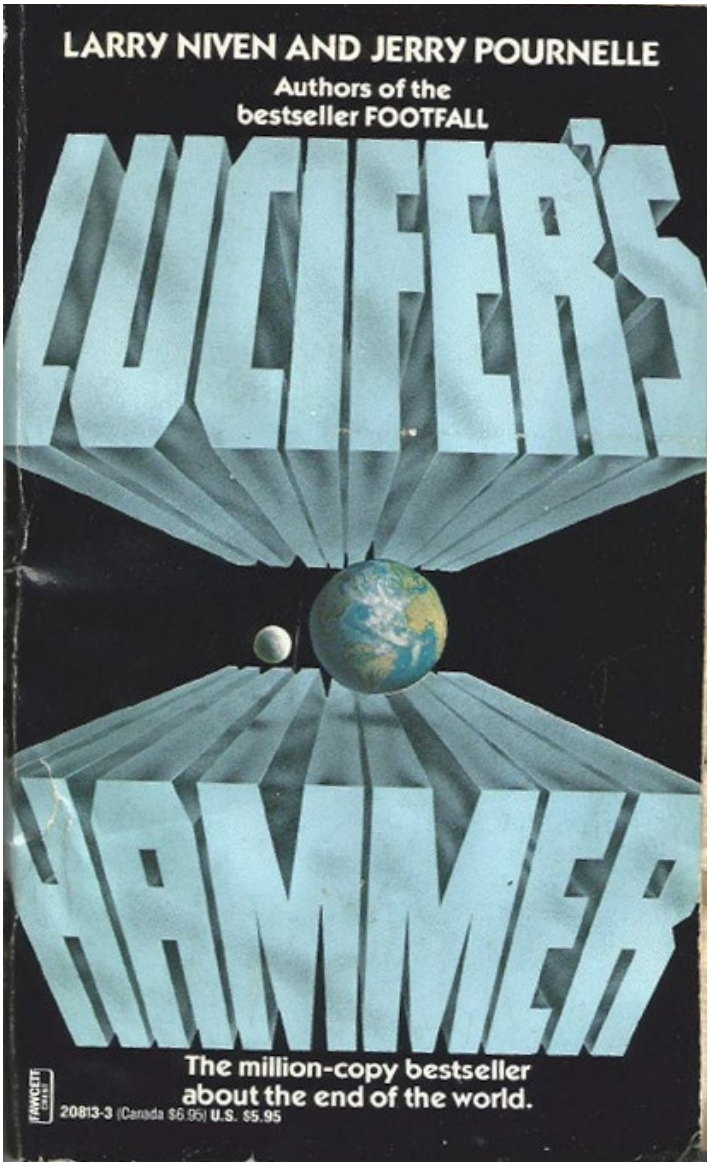
Another example is the "Comet of the Week" from two weeks ago, the Great Comet of 44 B.C. that was widely perceived as being the soul of the recently-assassinated Julius Caesar being transported to heaven. It is depicted as such in Ovid's "Metamorphoses" and is also alluded to in a line in William Shakespeare's play "Julius Casear." (The specific citations are quoted in that presentation.)

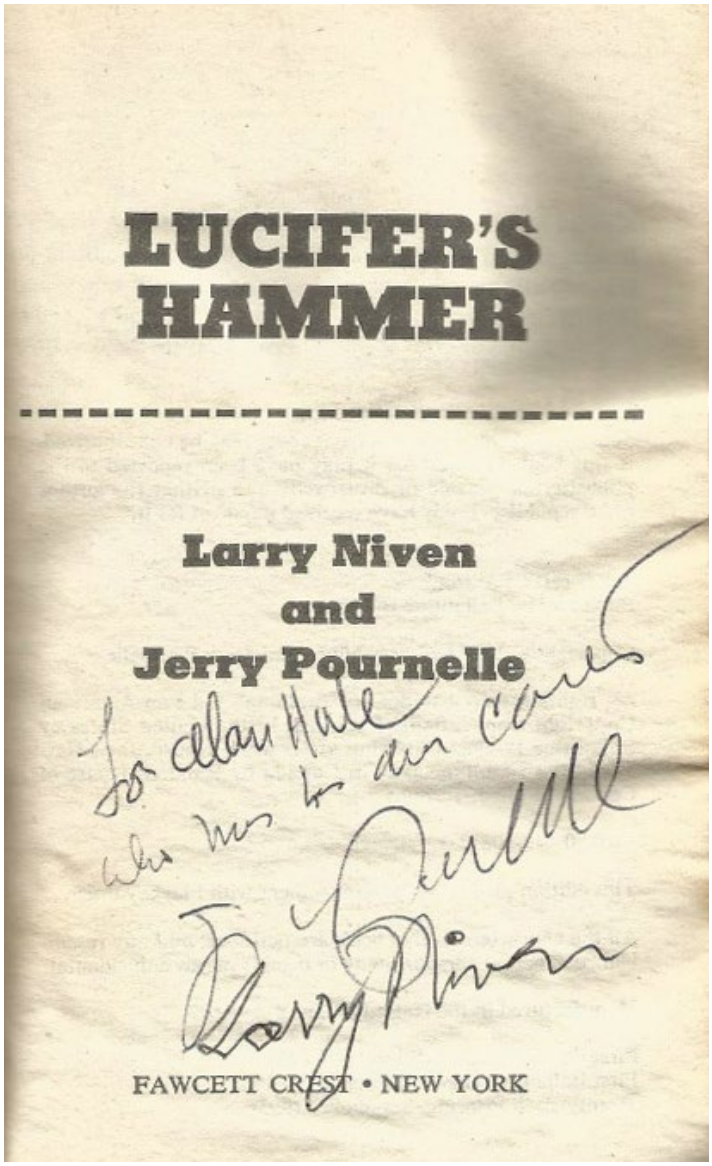
The Great Comet of 1811 – a future "Comet of the Week" – had a rather significant impact on some of the culture of the time, and was featured in several pieces of literature. Among these was Leo Tolstoy's novel "War and Peace," where it is described as being observed by the character Pierre Bezukhov (although the year is incorrectly given as 1812). The 2012 musical production "Natasha, Pierre & The Great Comet of 1812," which is based upon a segment of "War and Peace," also includes Pierre's sighting of the comet. The port wine vintage from 1811 happened to be exceptionally good, and for many years thereafter "Comet Wine" was marketed and sold at high prices.

Stories involving fictional comets have been written and published on a relatively frequent basis. Two from prominent "classical" science fiction writers include "Off on a Comet" by Jules Verne (published in 1877) that describes a group of people carried away on a comet that has hit Earth and continued on, and "In the Days of the Comet" by H.G. Wells (published in 1906) that describes a world transformed by the gases of a comet that encounters Earth. A 1986 anthology, "Comets," edited by Isaac Asimov, Martin Greenberg, and Charles Waugh contains several short stories of this nature, including one featuring the aforementioned "Comet Wine."

Incidentally, Jules Verne's 1870 novel "Around the Moon" – a sequel to his classic 1865 novel "From the Earth to the Moon" – features as one of its plot elements a small asteroid that is a second moon of Earth. While this particular object is fictional, at least two temporary "second moons" of Earth – both roughly the same size as the object in Verne's novel, although much more distant – have been discovered within the fairly recent past, and these objects are discussed as part of a future "Special Topics" presentation. Another Jules Verne novel, "The Chase of the Golden Meteor," published posthumously in 1908, takes a somewhat satirical look at attempts to claim credit for and retrieve a small impacting object found to be made of gold.

Among "small bodies" short stories, an interesting one is "The Colour Out of Space," published in 1927 by horror writer H.P. Lovecraft, and which concerns





The 1977 novel "Lucifer's Hammer" by Larry Niven and Jerry Pournelle. Left: Front cover. Right: Title page of my copy, autographed by Niven and Pournelle.

undesirable effects on the surrounding human populace following a meteorite fall. (The story has since been adapted into several movies, including "Die, Monster, Die!" in 1965 and "The Curse" in 1987.) Two notable "small bodies" stories by renowned science fiction writer Arthur C. Clarke are "Hide-and-Seek," published in 1949, which takes place on Phobos, and "Jupiter Five," published in 1953, in which an expedition to this moon – Amalthea, although it is not named within the story – turns out to be an alien artifact. A more recent interesting story is the 1986 novel "Heart of the Comet" by science fiction writers David Brin and Greg Benford, about an expedition to Comet Halley during that object's next return in 2061. Arthur C. Clarke's 1987 novel "2061: Odyssey Three" also begins with an expedition to Comet Halley in 2061, although the focus soon shifts elsewhere.

The subjects of comets and/or asteroids striking Earth, and the efforts to stop such an event from happening and/or the aftermath of such an event, are fairly common staples in a number of stories. Not all of such stories are especially accurate from a scientific standpoint, of course, and many of them take what could charitably be called "liberties," presumably for artistic purposes. One of the more engaging, and scientifically accurate, such stories is the 1977 novel "Lucifer's Hammer" by science fiction writers Larry Niven and Jerry Pournelle, which describes the impact of a giant comet onto Earth and the effects on humanity afterward. Curiously, and which was first pointed out to me by the late Director of the Minor Planet Center Brian Marsden, the initials of the comet in "Lucifer's Hammer," Hamner-Brown, are the same as those of Comet Hale-Bopp.

Another novel of that subject matter that is quite valid from a scientific standpoint is "The Hammer of God" by Arthur C. Clarke that was published in 1993. The discovery and deflection/impact scenarios depicted

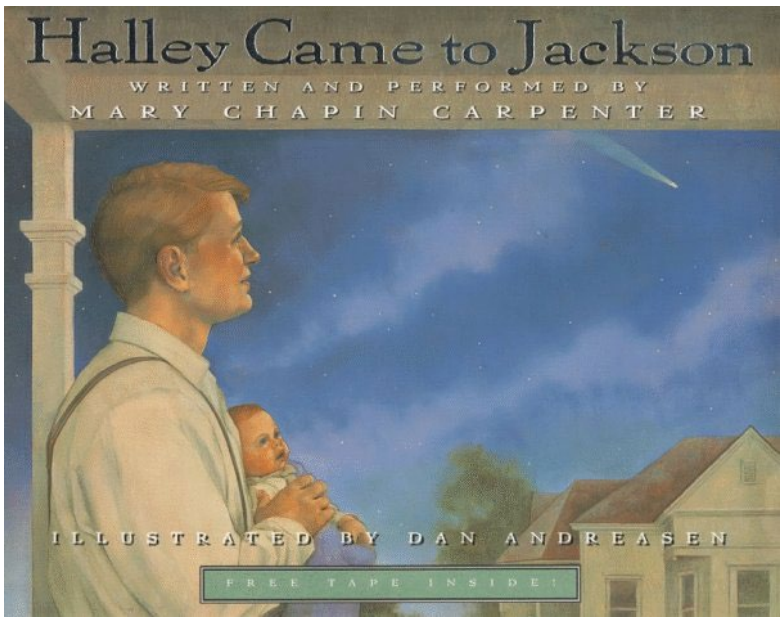
within "The Hammer of God" are quite plausible, and the story was inspired in part by the recent appearance of Comet 109P/Swift-Tuttle – the parent comet of the Perseid meteors, and a future "Comet of the Week" – which does pose a potential threat to Earth sometime in the future.

Depictions of this same theme in television and motion pictures run the spectrum from scientific plausibility to scientific nonsense, although most have tended to be on the less scientifically valid side of things. The 1995 Simpsons episode "Bart's Comet" (which first aired less than six months before the Hale-Bopp discovery) could be considered an example of this, although since this was written and televised for satirical value it can certainly be appreciated on that basis. On the other hand, what perhaps can be considered a counter-example is the Star Trek original series episode "The Paradise Syndrome" (1968) which, while it does not take place on Earth, addresses this theme, including attempts at deflection, in a reasonably valid manner.

Logo of the musical "Natasha, Pierre, & The Great Comet of 1812"

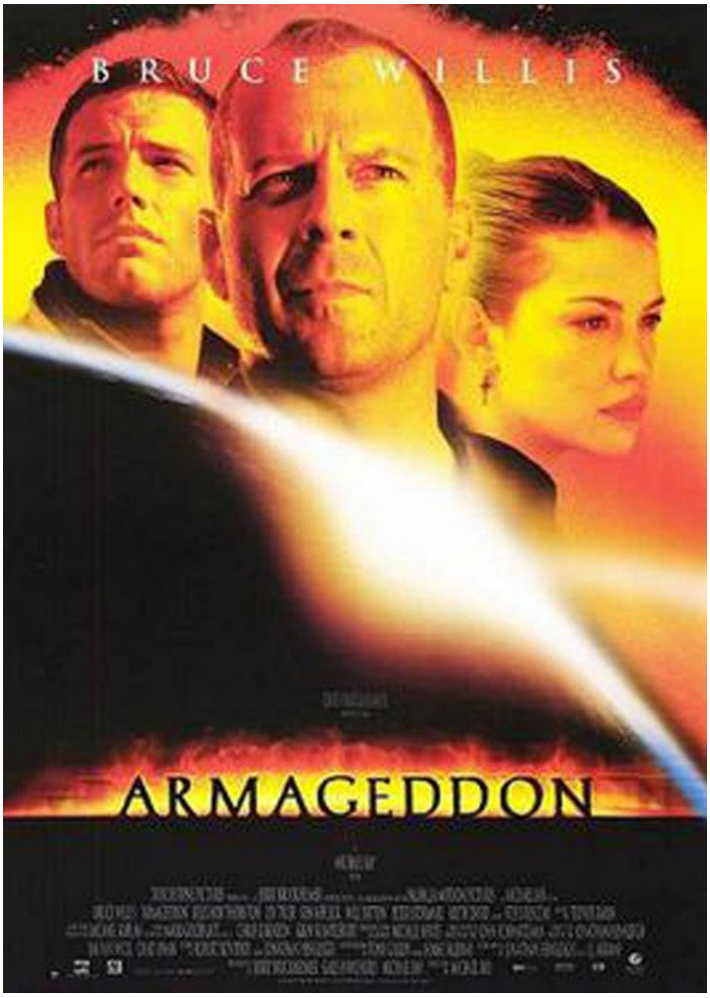
One of the earlier movie depictions of this theme was "When Worlds Collide," released in 1951 (and based upon a 1933 novel written by Philip Wylie and Edwin Balmer). The idea of an unknown "rogue" star and planet entering the solar system and colliding with Earth is very implausible from a scientific perspective, although the movie's overall plot is consistent with the "nuclear disaster" theme that was common for films of that era.

Most of the other movies of this theme that have come out since that time are at least as scientifically unrealistic as "When Worlds Collide" and are hardly worth mentioning. Two which are – both being big-budget productions – came out in 1998, shortly after the impacts of Comet Shoemaker-Levy 9 into Jupiter in 1994 and the two "Great Comets" Hyakutake (1996) and Hale-Bopp (1997). "Armageddon" can perhaps be enjoyed for its entertainment value, but scientifically is so unrealistic that it has been reputed to be a NASA training vehicle, to wit, how many errors can be spotted? (Supposedly, that list is over 150 items long.) The main premise, i.e., a previously-unknown asteroid "the size of Texas" headed towards Earth, is itself extremely implausible, since the only known inner solar system asteroid of that size, (1) Ceres, was discovered two centuries ago, and anything comparable could not have escaped detection during the intervening decades. "Deep Impact" (which mentions Comet Hale-Bopp) does feature reasonably plausible impact effects, although the impacting comet's discovery scenario – which forms a significant element of the plot – is itself implausible.



Front cover of the picture book "Halley Came to Jackson," written by Mary Chapin Carpenter and illustrated by Dan Andreasen, based upon her song of that name.

A story addressing a different theme that has turned out to be remarkably prescient is Arthur C. Clarke's 1973 novel



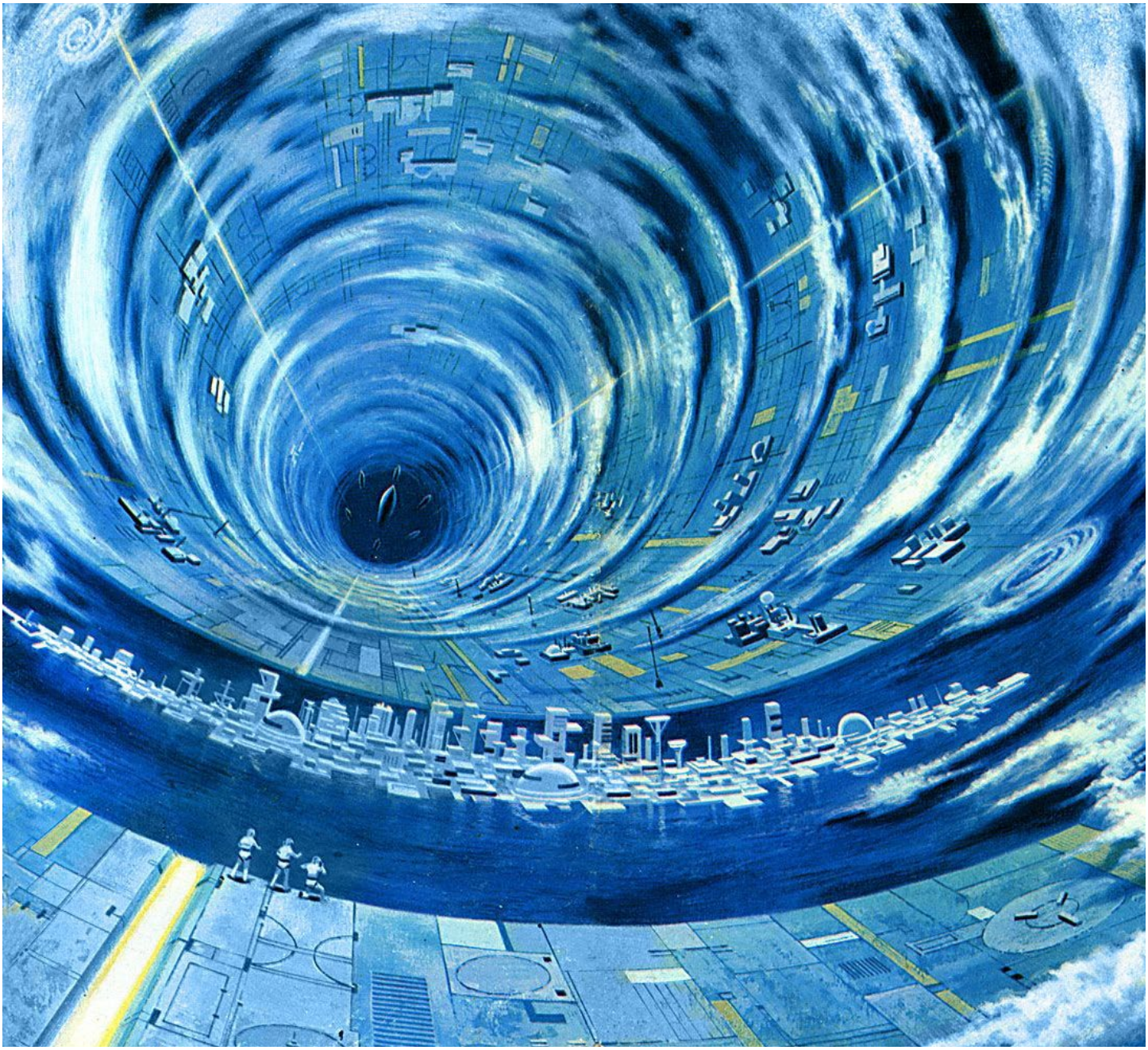
Posters for the 1998 motion pictures "Armageddon" (left) and "Deep Impact" (right)

"Rendezvous with Rama," which describes the exploration of an interstellar object – that turns out to be a large, seemingly uninhabited alien spacecraft – passing through the inner solar system. (As a part of the novel, the object "Rama" was discovered via a worldwide survey program dubbed "Spaceguard" that was developed after Earth was hit by a small asteroid in the year 2077 that created significant devastation; that same name is used now as an umbrella term for the current survey programs as an homage to Clarke.) The story of the interstellar object 'Oumuamua that appeared in 2017 (and that is the subject of a future "Special Topics" presentation) is eerily similar to that of the fictional Rama, although – thus far, anyway – 'Oumuamua appears to be a natural object. As for the ending theme that "the Ramans do everything in threes" (that was explored in sequels co-authored with Gentry Lee), we'll have to wait and see about that.

Most music that has been written about astronomical objects within the solar system has tended to focus on the sun and moon or on one or more of the other major planets. As for "small bodies" musical examples, I've already mentioned the 2012 musical "Natasha, Pierre, & the Great Comet of 1812" – with its concluding piece, "The Great Comet of 1812," sung (in studio recordings) by Josh Groban – that was adapted from a segment of Leo Tolstoy's "War and Peace." Other notable pieces include the ragtime "Halley's Comet Rag" written by Harry J. Lincoln in 1910 and the jazz piece "Stars Fell on Alabama" – a descriptive reference to the 1833 Leonid meteor storm – written in 1934 by Frank Perkins and Mitchell Parish, and first recorded by the Guy Lombardo orchestra.

Among more recent songs about "small bodies," one of my personal favorites is "Halley Came to Jackson" by Mary Chapin Carpenter (from her 1990 album "Shooting Straight in the Dark"), which describes the true story of the writer Eudora Welty who was shown Comet Halley as a baby in 1910 and who saw it again during its return in 1986 (although the lyrics include the misperception that a comet will "shoot across the sky"). Less well known, but also nice, is "St. Judy's Comet" by Paul Simon (from his 1973 album "There Goes Rhymin' Simon"). Quite a few other songs by lesser-known artists, of comets both real and fictional, have been released over the years.

Of particular interest to me, for obvious reasons,



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."

are the various songs that were written about Comet Hale-Bopp around the time of that object's appearance in 1997. Many of these are quite obscure and, in all honesty, rather forgettable, although one notable piece is "Hale-Bopp, Hip-Hop" by jazz musicians Herbie Hancock and Wayne Shorter from their 1997 album "1+1." I'll have to confess that my favorite Hale-Bopp song is the provocatively-titled "Hale-Bopp Regurgitations" by R&B duo P.M. Dawn (from their 1998 album "Dearest Christian, I'm So Very Sorry for Bringing You Here. Love, Dad"), which takes a sardonic look at some of the national events going on around that time.

I perhaps should also mention that a trilogy of movies currently in development under the working title of "The Animator" features Comet Hale-Bopp as one of the plot elements in the second installment. I am assisting to some extent in the development of this movie project and for the time being am not at liberty to say much about it, but would ask "Ice and Stone 2020" participants to keep a watch for it sometime within the next two to three years.

Meanwhile, those "Ice and Stone 2020" participants who are interested and so inclined can search for the numerous other examples of stories and songs about and/or inspired by the solar system's "small bodies." Or, perhaps, participants can write some of their own, and if they wish can share them with the rest of us . . .

www.halebopp.org

www.iceandstone.space