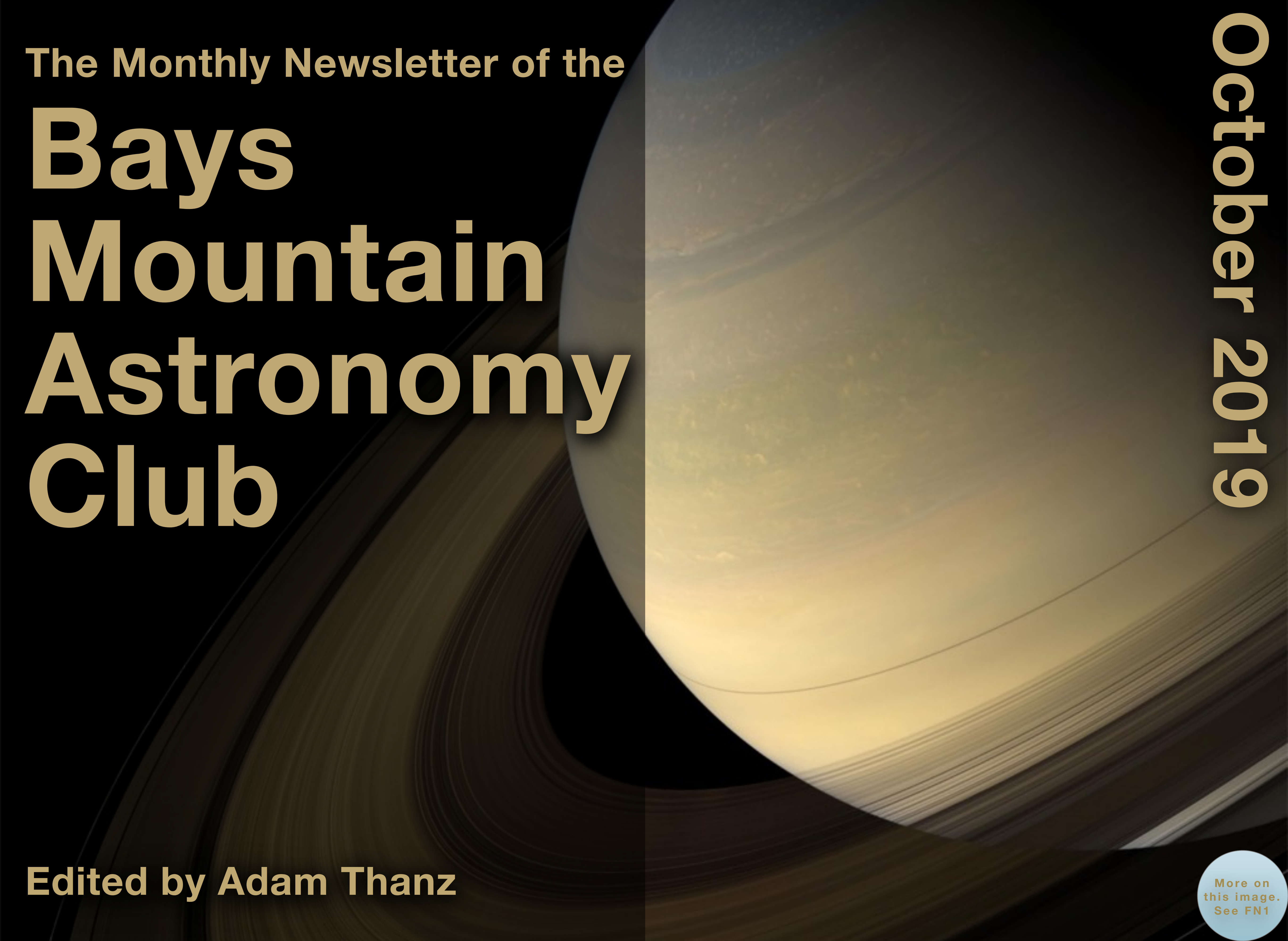
The Monthly Newsletter of the

Bays Mountain Astronomy Club

October 2019



Edited by Adam Thanz

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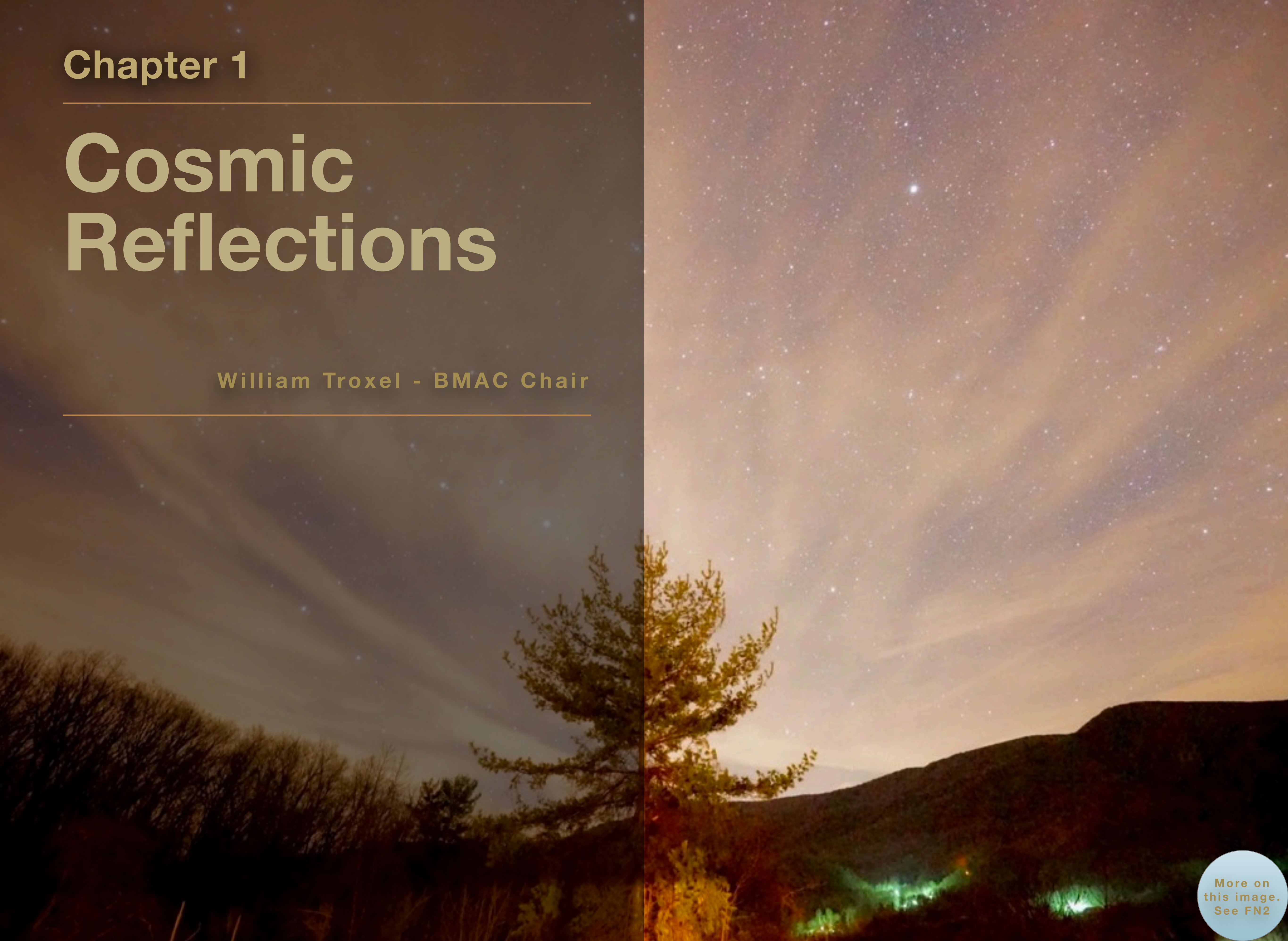
Chapter 1

Cosmic Reflections

William Troxel - BMAC Chair



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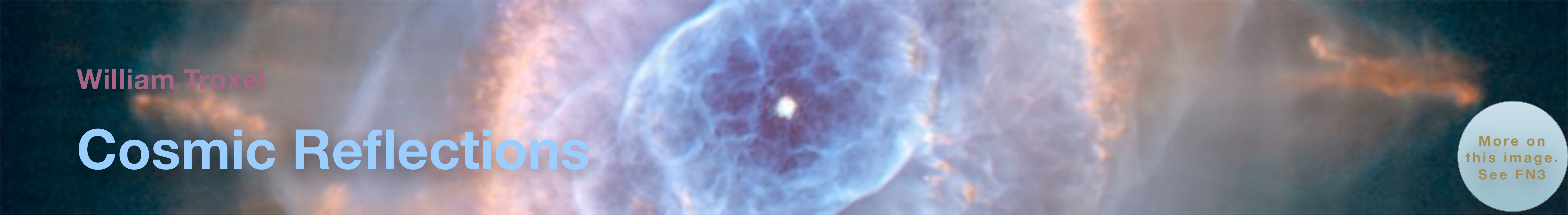


William Troxel

Cosmic Reflections

Greetings BMACer's

It is hard to believe that October is upon us all ready. October is a very big month for the club. More on that later in the article.

First, I want to thank a few people from September's meeting. I want to thank Brandon Stroupe for hosting and running the business part of the September meeting. I know that Brandon did a wonderful job in my absence. Next, I want to thank Robin Byrne and John Hay for being willing to help out with the research for the Solar System Walk game that will be part of the 2020 Astronomy Day activities. I will be sharing the next steps with you over the next few months.

I wanted to also thank Dr. Richard Ignace, Professor and Astrophysicist from ETSU for being our featured speaker. All the reports I received told me that his presentation was well received. Thank you again for coming and presenting your work.

I promised to write about the upcoming month of October for the Astronomy Club. October, in case you are new to the club or reading my article for the 1st time, is a big month for us. October includes both the start of the fall StarWatch public night viewings and our annual StarFest 3-day event.

StarWatch is our free, public night viewings at the observatories. They are held on the Saturday nights of October and November (and March and April) starting at dusk. If the weather is clear, we'll be sharing the night sky with the general public. If the weather is poor, there will be an alternate program in the planetarium theater. If you would like to help with the StarWatch programs and interact with the public, you'll need to go through the volunteer program from the Park first. If you want to learn the night sky and attend like the public, then please attend and learn!

StarFest is the annual astronomy weekend which we are co-hosts with Bays Mountain Park. This is a separate event which only registered attendees that have pre-paid will be able to attend. Delegates will enjoy a full weekend of four different speakers, great food at the park and more. Adam will be covering this more later in the newsletter. When you are reading this article, the registration period might still be open for this years event. Registration closes Sept. 27.

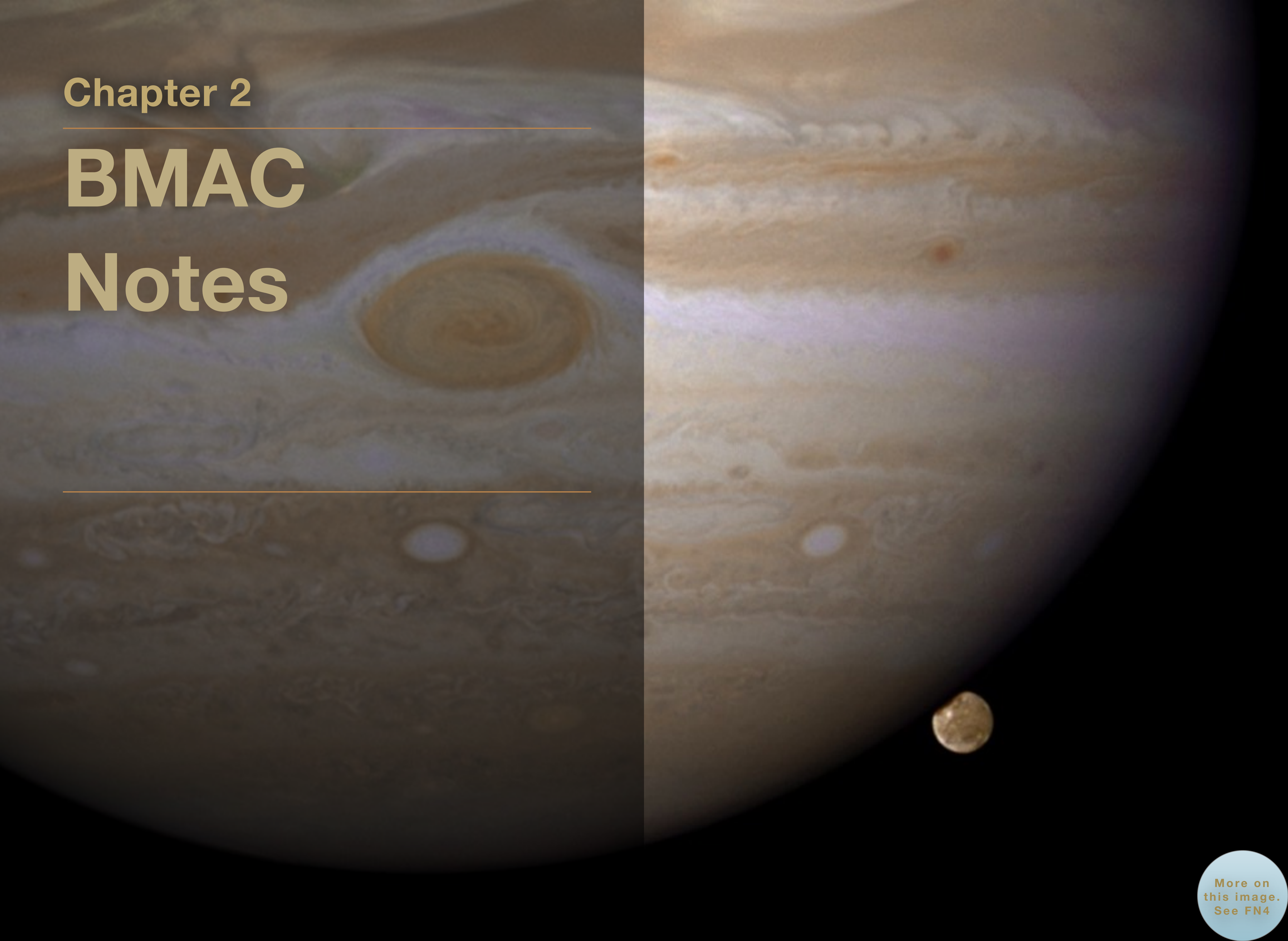
This month's meeting will focus on getting both of the observatories ready for the evening events during StarWatch and StarFest. Note: The meeting will start at 6 p.m.! We will also be having a club member observing session after the clean up is completed. Please bring cleaning supplies, shop vacs, rags, brooms, etc. The more hands, the faster we'll finish. While we are waiting for dark, we'll have some fun with what I am calling "The Four Tens." We will have up to four members that have been pre-selected to do a 10 minute maximum presentation on an astronomy subject that will be both creative and fun. If the weather does not cooperate, we will come into the Discovery Theater and do "The Four Tens."

I hope every one can come out and help with the clean up, observing and enjoy "The Four Tens." Until next time…

Clear skies.

Chapter 2

BMAC Notes



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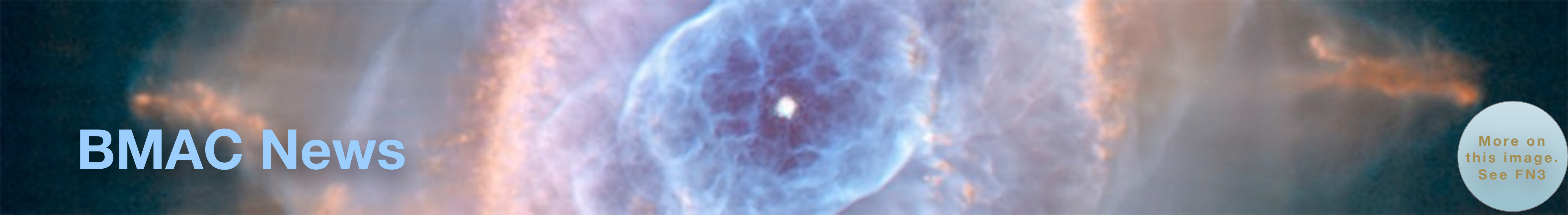
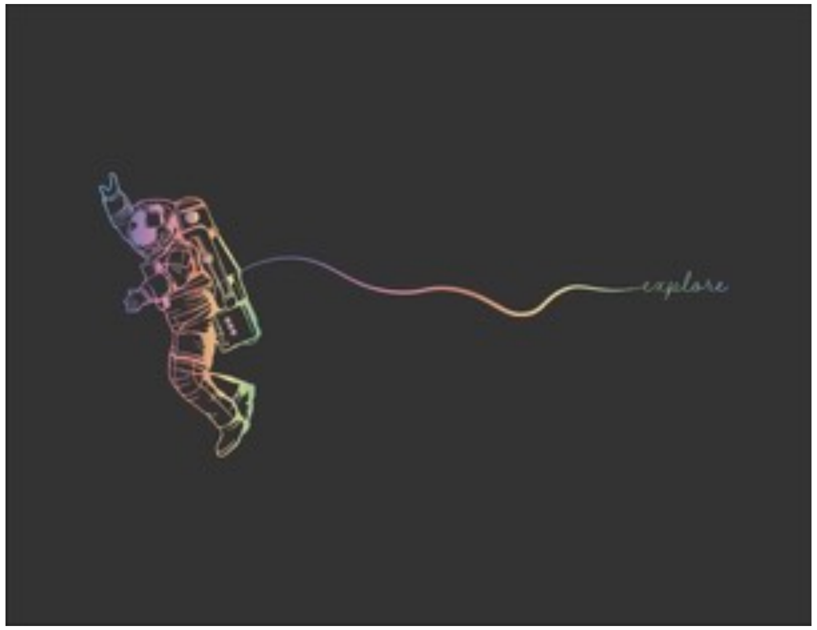




StarFest 2019 - Registration Closes Sept. 27!

The annual 3-day StarFest event is soon upon us! If you are interested in attending, I must have all registrations in by Sept. 27.

We have quite a shindig planned with 5 fabulous meals, 4 super keynote speakers, 3 days of excitement and learning, 2 nights observing, and 1 exceptional commemorative T-shirt!

The complete registration information can be found here.

The one-page registration sheet can be found here.

TN Academy of Sciences 2020

ETSU plans to host the annual meeting of the TN Academy of Sciences for November 2020. It will cover all areas of STEM plus health. It's been about 25 years since ETSU hosted this event! It's a short meeting and is planned to be held on a Saturday. Here's the link to learn more:

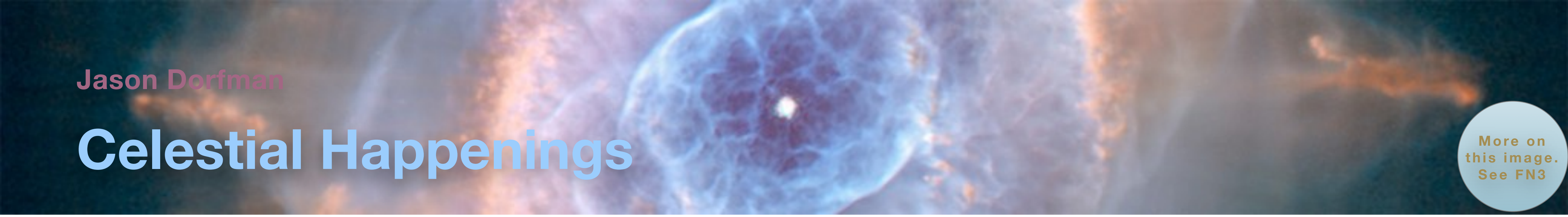
http://www.tennacadofsci.org/

Chapter 3

Celestial Happenings

Jason Dorfman

More on this image. See FN5



Jason Dorfman

Celestial Happenings

The immediate region of space surrounding Earth is about to get a lot more crowded. On May 23 of this year, SpaceX launched its first group of 60 satellites for its StarLink constellation program. In their initial orbit of 440 km, the long train of satellites, ranging in magnitude from 1st to 3rd, was easily visible (image 1). Most have now dimmed to 5th or 6th magnitude as they've spread out and climbed to a higher orbit of 550 km (342 miles). However, this is only the first of many similar launches to come. What does this mean for amateur and professional astronomers who have to look through this array of satellites to view the space beyond?

What is StarLink?

StarLink is SpaceX's plan to provide broadband internet to the entire globe by placing an array of almost 12,000 satellites spread around the planet in low-Earth orbit (image 2). The hope is to help improve connectivity to remote areas and decrease latency for long distance communications. Currently, information around the globe is delivered mostly by fiber-optic cables, which introduces noticeable lag time when sending information around the globe. It is most evident in global video communications, but reducing latency is also important to the international financial market. Light moves 47% faster through the vacuum of space than it can through solid fiber-optic cable, so a space-based array of satellites will reduce the lag times for global communication and delivery of information.

Each satellite features a compact, flat-panel design that helps to minimize its volume and allows them to be stacked together in a dense launch configuration (image 3 & 4). The satellites each have 4 powerful phased array antennas that will allow an enormous amount of throughput to be placed and redirected in a short amount of time (image 5), a single solar array, and a krypton powered ion thruster system (image 6) - the first of its kind.

The 60 satellites were launched aboard SpaceX's Falcon 9 rocket. At 18.5 tons, this was the heaviest payload to date for the Falcon 9 rocket. Three satellites were initially DOA after launch and will simply deorbit as Earth's gravity and atmospheric drag pull them down until they burn up in the atmosphere. Once in orbit, the satellites began to separate and maneuver away from one another.

The initial satellites were not all identical and are not the final design. SpaceX implemented slight variations across the 60 satellites to test out different technologies in an effort to determine the best and most efficient design for future spacecraft builds. The initial 60 also lack the inter-satellite links expected for future models. Future satellites will link to 4 others using lasers allowing them to beam data around Earth at nearly the speed of light (image 7).

At present, 10 satellites have been decommissioned, some for unknown reasons. In addition to the 3 that were DOA, SpaceX purposely deorbited a few more using the ion propulsion system as a test of this capability. The others are likely ones that failed due to the different components used.

Before the end of 2019, we should see two more launches of 60 StarLink satellites each as SpaceX begins a more regular launch schedule to reach its goal of a total of 360 satellites by the end of 2020. This is the number of satellites needed to begin to offer service in the Northern U.S. and Canadian latitudes. After 24 launches or about 1500 satellites, they will be able to expand this to global coverage. Beginning next year, SpaceX plans to launch StarLink Satellites about 9 times a year continuing this over the next decade to reach its goal of 11,800 satellites.

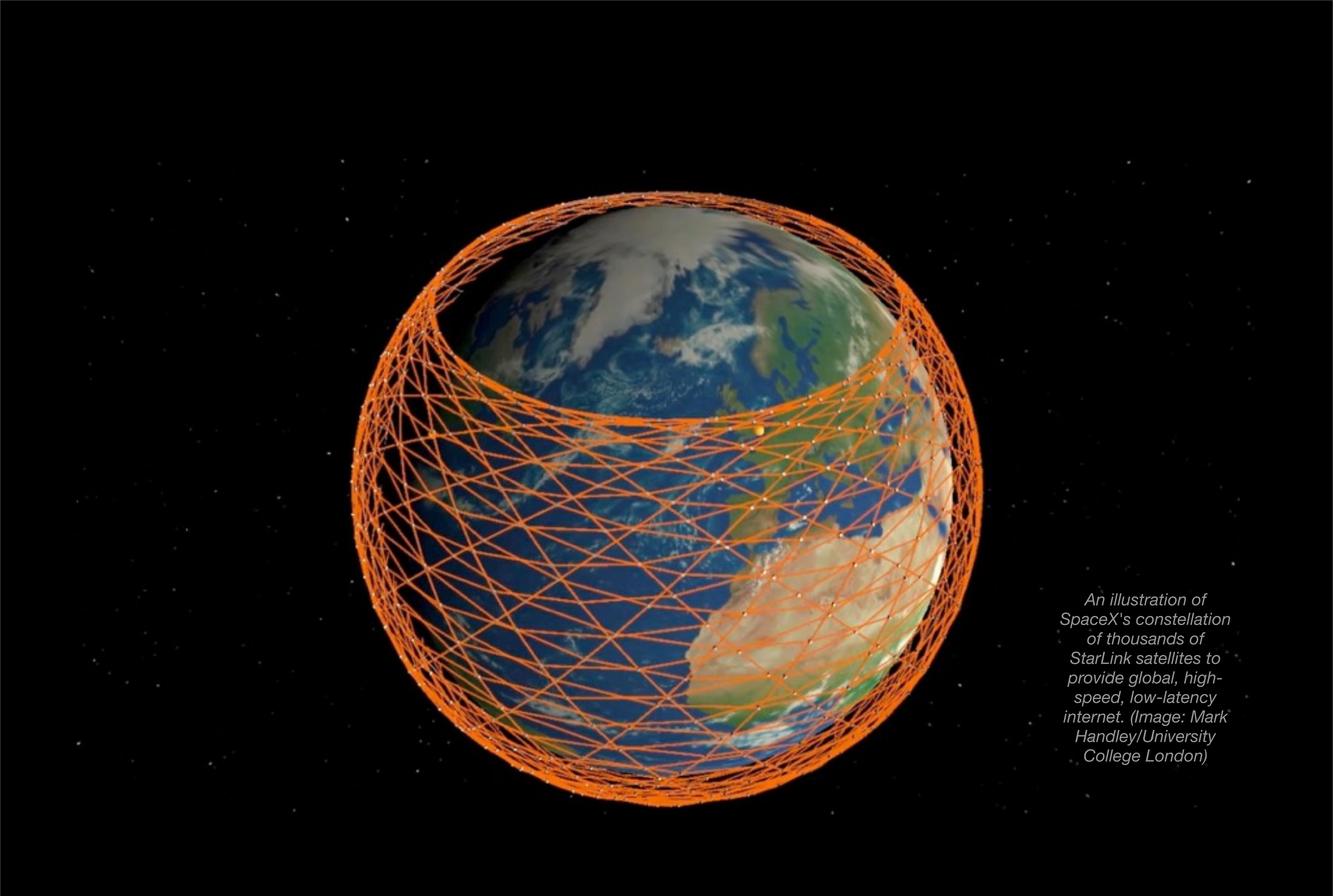
SpaceX is not the only company with plans for a satellite internet communications system, but they are definitely leading the way and setting the bar high, as they've done with many of their other programs. OneWeb, a London-based company, launched 6 of an initial 648 satellites on February 27th. The company plans to begin monthly launches soon to reach its full operational status sometime in 2021. They will operate at a higher orbit of 1200km than SpaceX's StarLink satellites. Kepler Communications of Canada launched 2 satellites of a planned 140 in February 2018. Other constellation companies like Telesat, LeoSat, and Amazon's Project Kuiper are still 2-5 years out from launching their first satellites, let alone offering any kind of service.

A Satellite Filled Sky

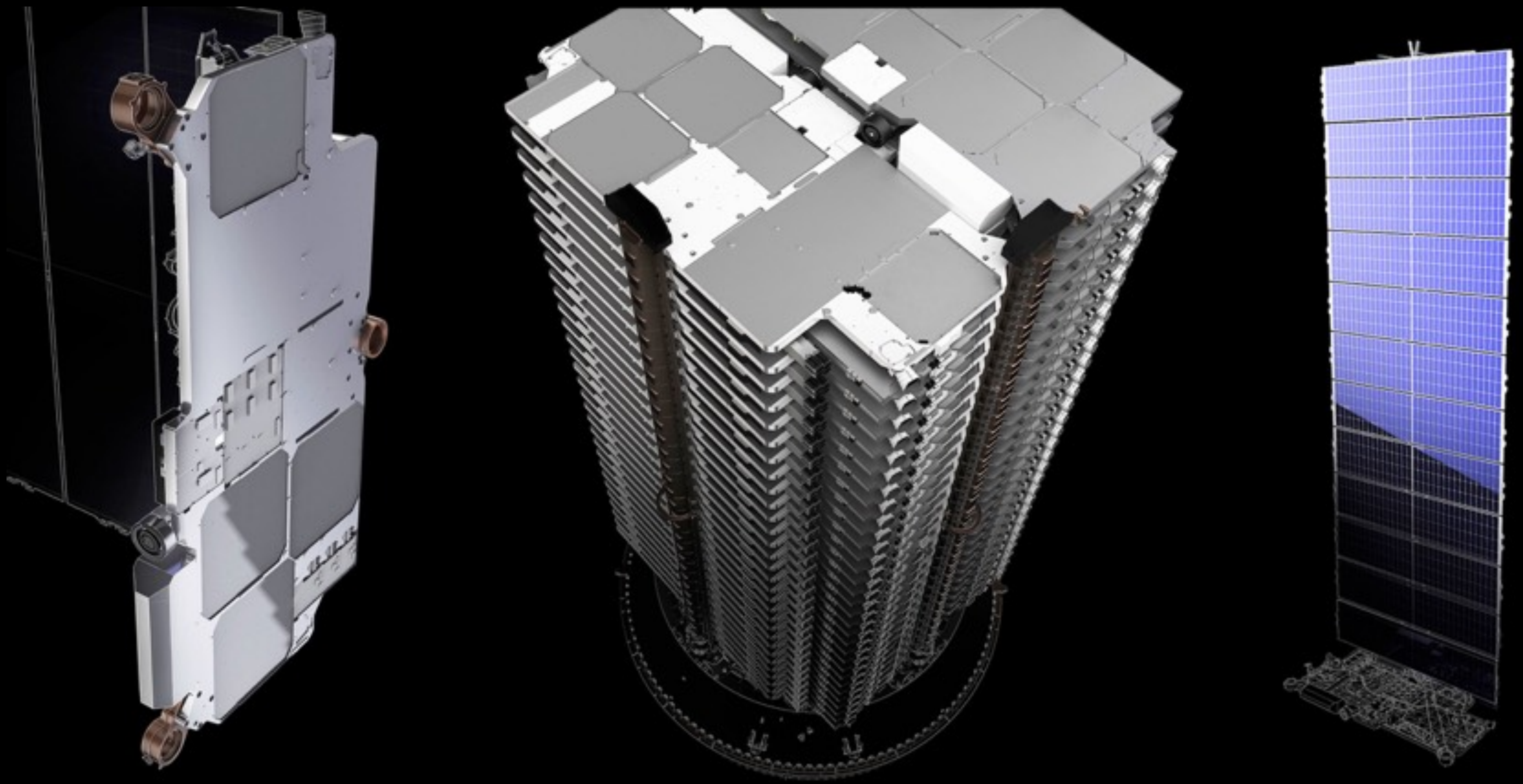
It looks like in the not too distant future we will have quite a few satellites in low-Earth orbit. The current plan from SpaceX is to place 1,584 satellites at an altitude of 550 km (342 miles) and an additional 7,518 at an even lower altitude of 340 km (211 miles). What the magnitude of these satellites will be remains to be seen. With just our eyes and a dark sky we can see about 7000 stars of magnitude 6 and brighter. The additional 7,518 lower altitude satellites are likely to be brighter than magnitude 6, which means the number of visible satellites may outnumber the visible stars! This will really change how we see the night sky. SpaceX claims to be working to reduce the albedo of the satellites so they are not as visible, but how effective this will be remains to be seen.

The StarLink satellite constellation is prominent enough that Heavens-above.com has added a dedicated link that displays a globe with the positions of the StarLink satellites.

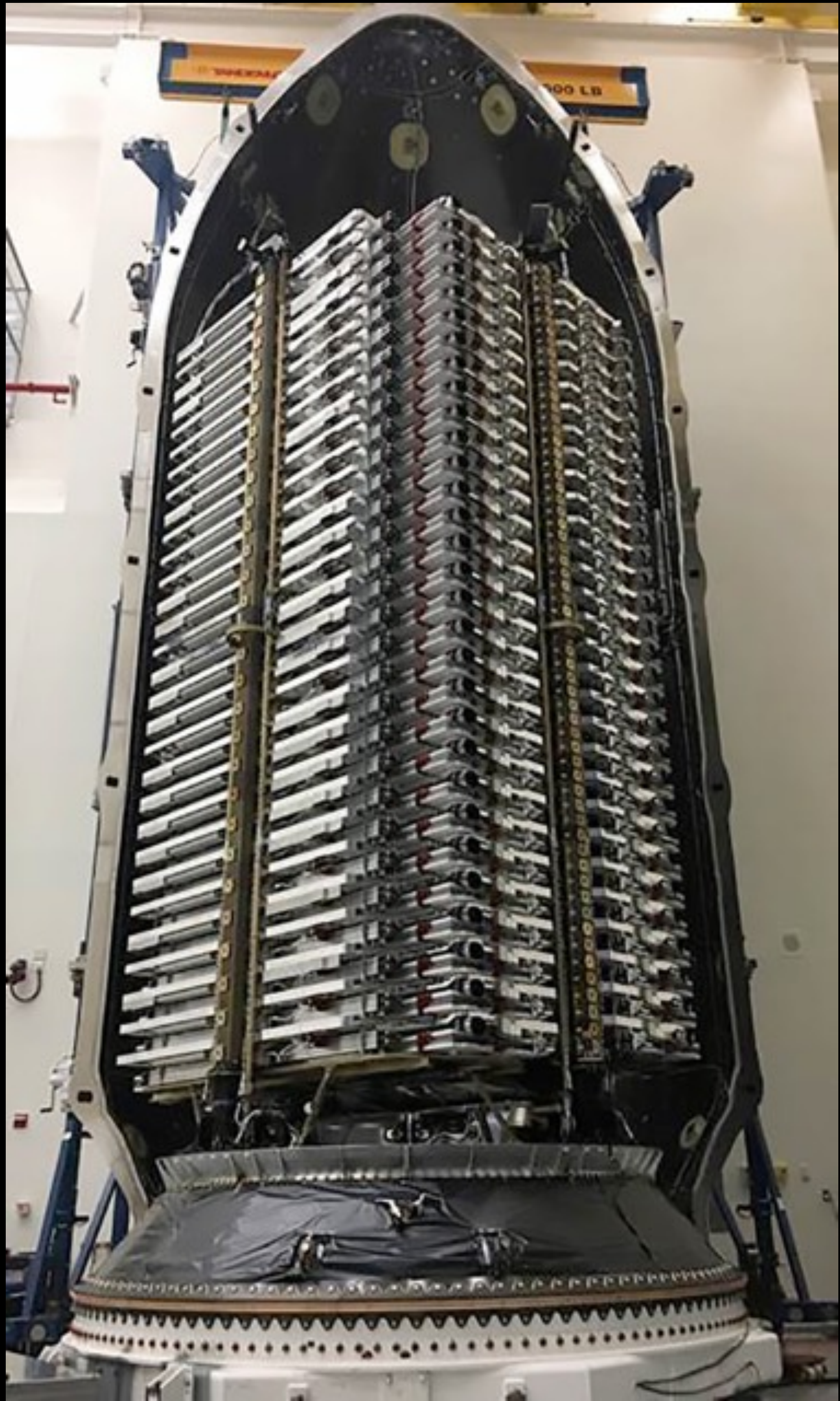
A train of SpaceX StarLink satellites are visible in the night sky in this still from a video captured by satellite tracker Marco Langbroek in Leiden, The Netherlands on May 24, 2019, just one day after SpaceX launched 60 of the StarLink internet communications satellites into orbit. (Image: ©Marco Langbroek via SatTrackBlog)



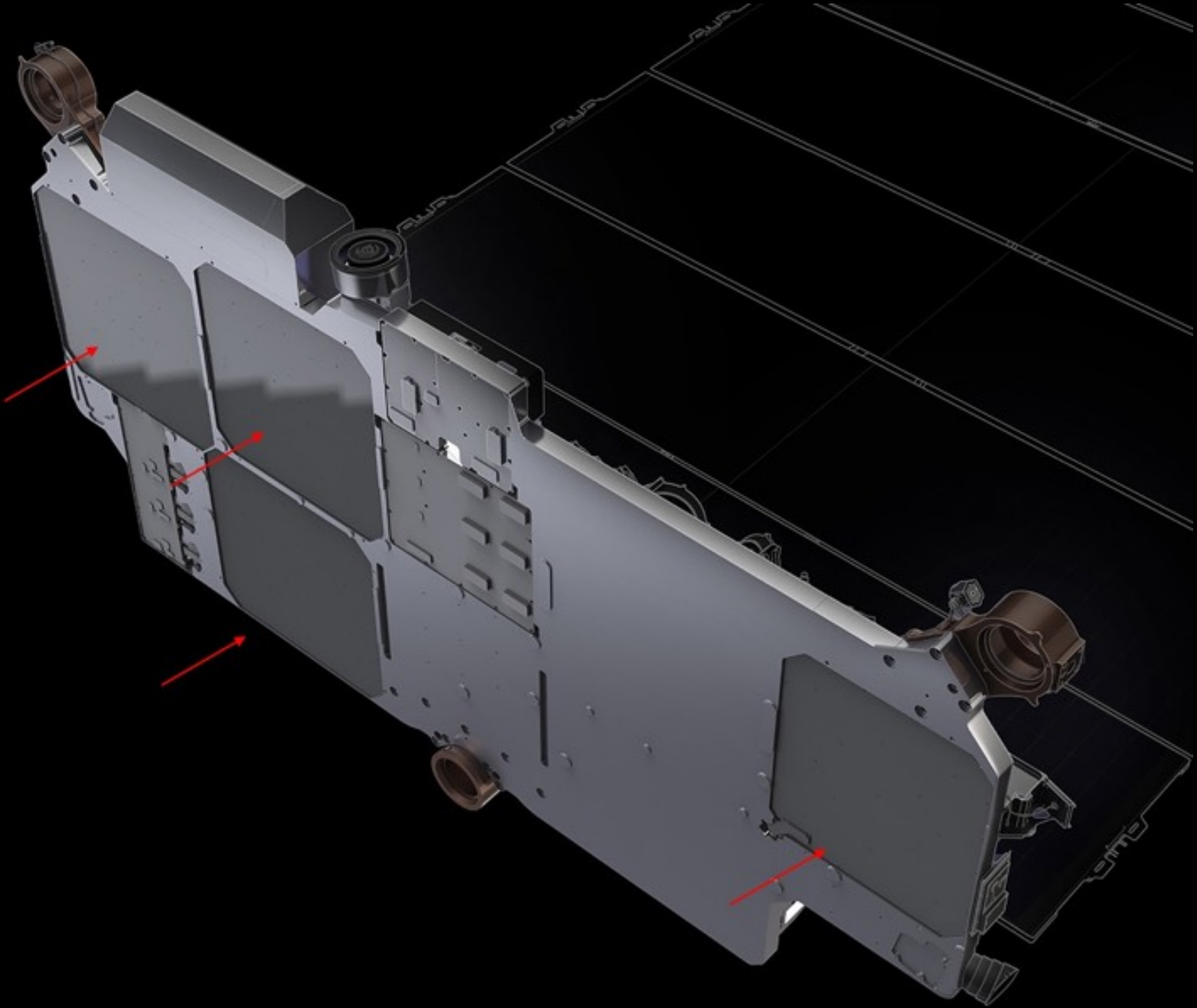
An illustration of SpaceX's constellation of thousands of StarLink satellites to provide global, high-speed, low-latency internet. (Image: Mark Handley/University College London)



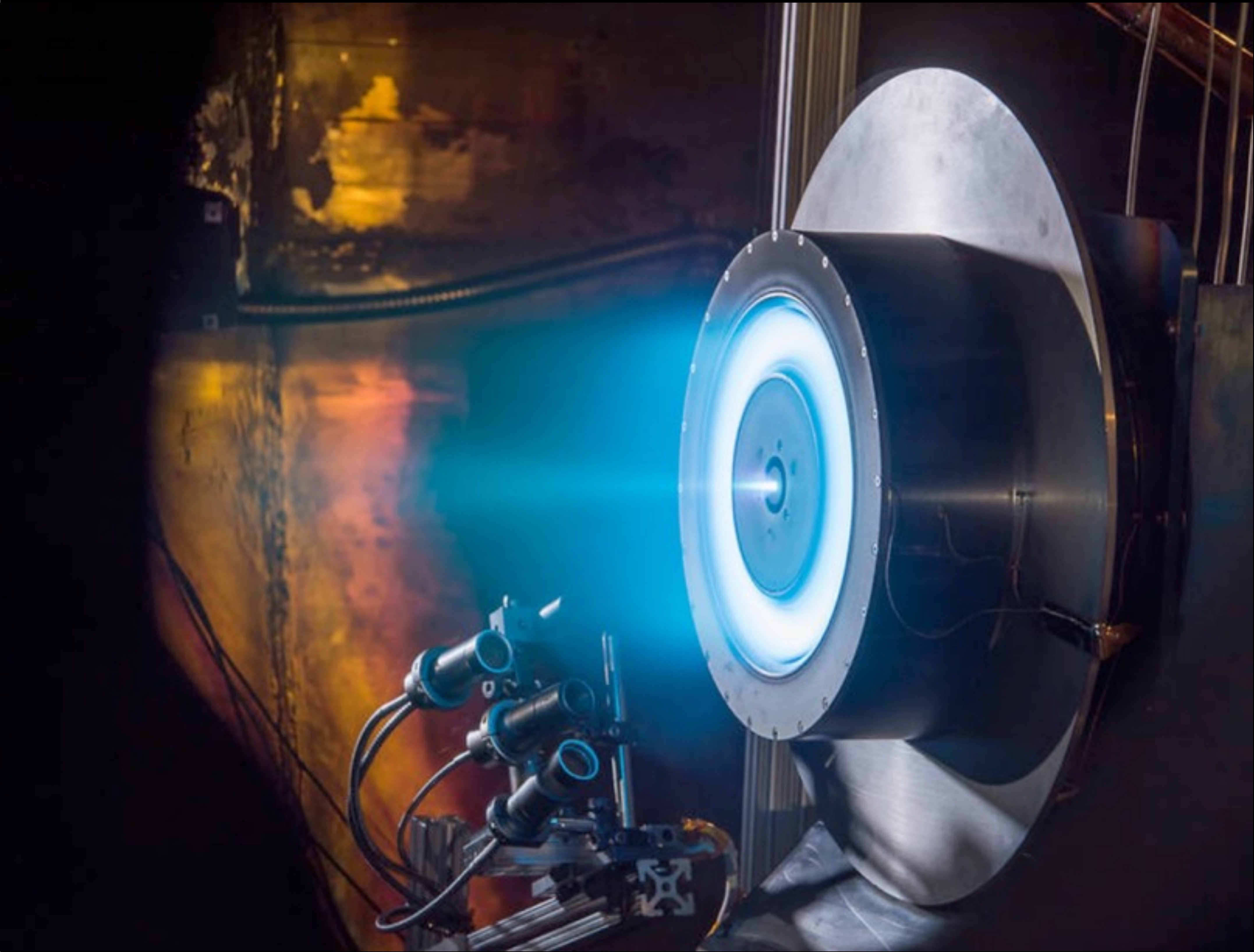
A general overview of StarLink's bus, launch stacking, and solar array. (Image: SpaceX)



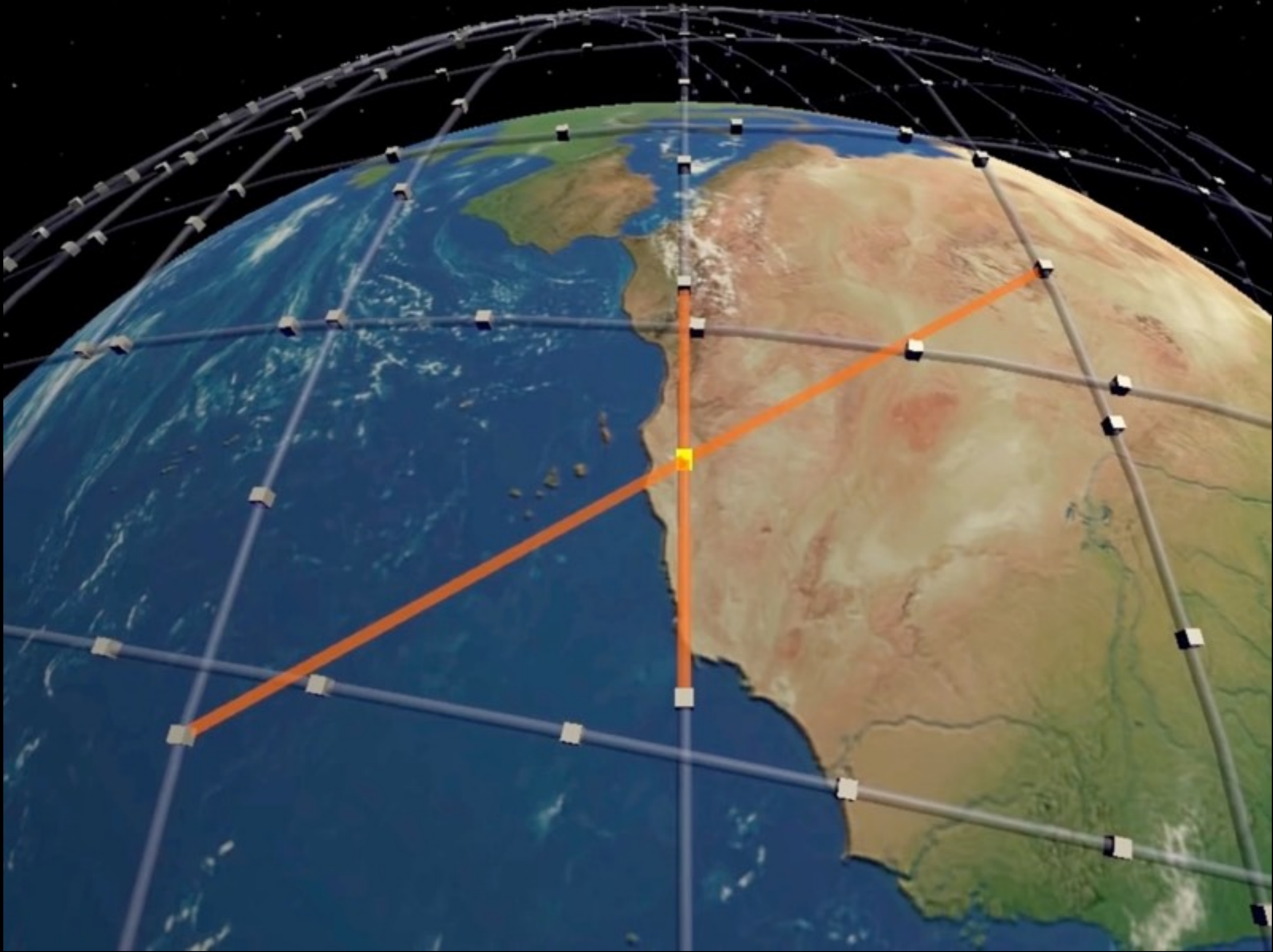
SpaceX stuffed a fleet of 60 StarLink internet-providing satellites into the nosecone of a Falcon 9 rocket for a launch in May. (Image: Elon Musk/SpaceX via Twitter)



Four 'phased array" radio antennas. (Image: SpaceX)



A 13-kilowatt Hall thruster, or ion engine, tested at NASA's Glenn Research Center. (Image: NASA)



An illustration of StarLink showing how each satellite connects to four others with laser beams. (Image: Mark Handley/ University College London)

Dynamic 3D display of all objects from the recent StarLink launch https://www.heavens-above.com/StarLink.aspx?lat=36.5089&lng=-82.6119&loc=Unnamed&alt=0&tz=EST

For most amateurs, the potential effects are likely to be only a nuisance. I have always enjoyed seeing the occasional satellite pass overhead, as well as catching the occasional ISS flyovers. Perhaps this will be a new way to get others interested in looking at the skies above. However, for the astrophotographers among us, you may find it more difficult to capture that wonderful deep-sky image without a satellite trail passing through your shot.

Currently, the next StarLink launch is planned for October 17, just in time for StarFest! Perhaps we'll be watching a bright train of satellites parading across the sky during the event.

References:

Henry, Caleb, 2019, Contact lost with three StarLink satellites, other 57 healthy, https://spacenews.com/contact-lost-with-three-StarLink-satellites-other-57-healthy/ (September 17, 2019)

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Mosher, Dave, 2019, Elon Musk just revealed new details about StarLink, a plan to surround Earth with 12,000 high-speed internet satellites. Here's how it might work, https://www.businessinsider.com/spacex-StarLink-satellite-internet-how-it-works-2019-5 (September 17, 2019)

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King, Bob (2019, September). SpaceX Launches 60 StarLink Satellites. Sky & Telescope, vol. 138, no.3, 9

https://www.StarLink.com (September 18, 2019)

https://www.oneweb.world (September 18, 2019)

https://en.wikipedia.org/wiki/StarLink_(satellite_constellation) (September 18, 2019)

Chapter 4

The Queen Speaks

Robin Byrne

Robin Byrne

Book Review: Walter Baade A Life in Astrophysics

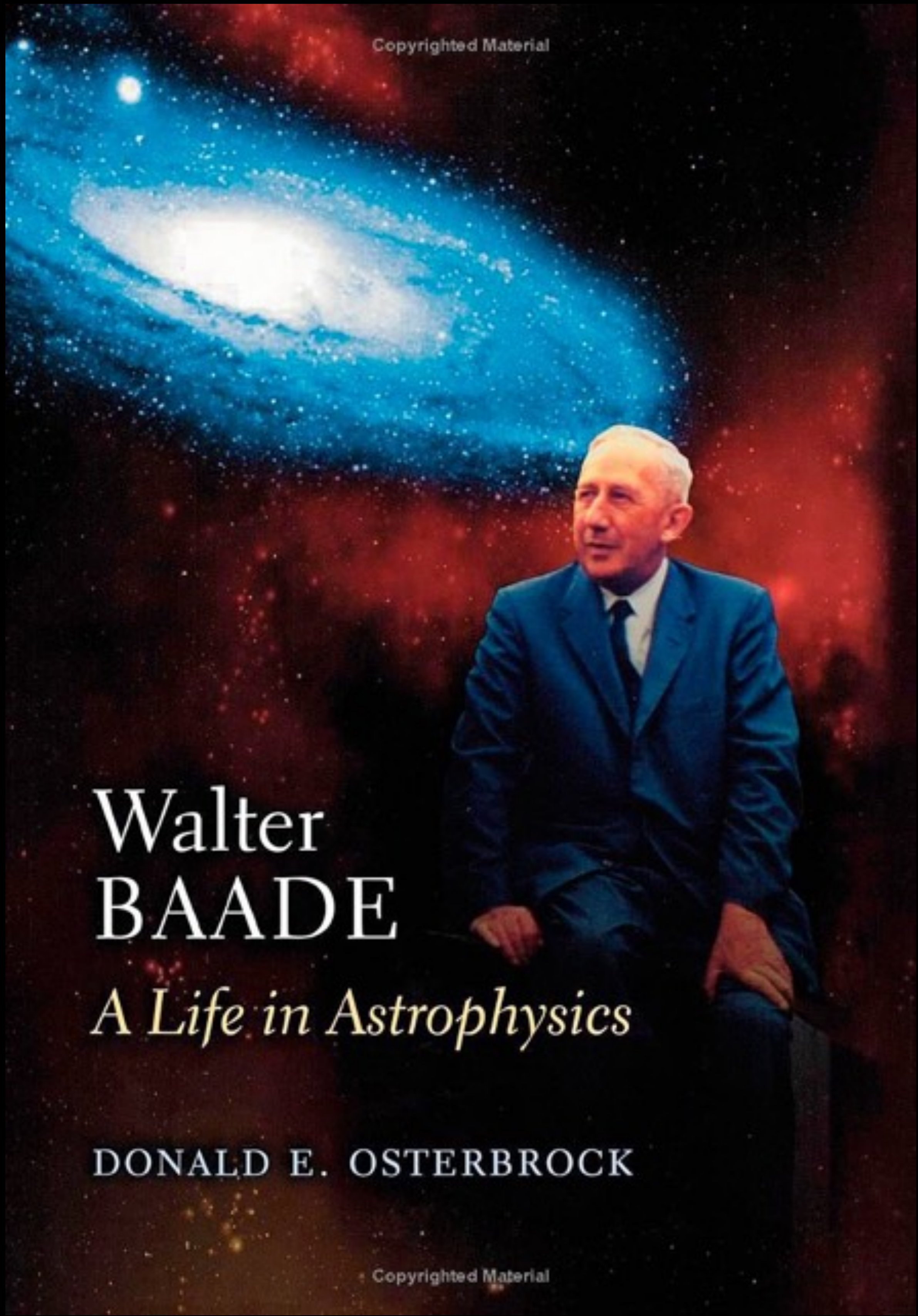
More on this image. See FN3

Sometimes it pays off to have eclectic taste. At the last Southern Star Astronomy Conference, there were many door prizes, but the one that caught my fancy was a book titled Walter Baade A Life in Astrophysics by Donald Osterbrock. I excitedly put my name in. Turns out I was the only one who wanted it, so I was the de facto winner! And I truly was a winner to have the opportunity to read this book.

I've taught my Astronomy 2 students about Walter Baade for ages, but this book gave me a more complete picture of the man and his accomplishments. The story begins with his early life in Germany and college career. From the beginning he was interested in studying stars. This would be a theme throughout his career. Baade also developed his exceptional observational skills while in Germany.

It didn't take long for Baade to become known outside of his home country. Between his publications and a trip across the United States to visit various observatories, Baade made himself known to several influential astronomers. It was through these connections that he was offered the opportunity to work on the staff of Mount Wilson Observatory. At the same time, Baade was offered the position of director of an observatory in Germany. While the directorship was tempting, the lure of larger telescopes under much clearer skies was too much of a draw, so Baade moved to the U.S. with his wife. The timing turned out to be serendipitous. A few years later, Hitler and Naziism rose to power.

During World War II, because Baade was still a German citizen, he could not join his Mount Wilson colleagues to work on war-related projects. Instead, Baade had almost exclusive access to the Mount Wilson telescopes. He made good use of that time, setting the groundwork for his most famous discovery. It was during this time that Baade began to notice different characteristics between stars in the halo of the Milky Way compared to those in the disk. This was the beginning of his classification system of halo star as Population II and disk stars as Population I. It would take many more years, and collaboration with many other astronomers, before it became clear why they were different. Stars in the halo are first generation stars, made primarily of hydrogen and helium. Stars in the disk are later generation stars, enriched with heavier



The cover to Walter Baade A Life in Astrophysics by Donald E. Osterbrock

Walter Baade, Mt. Wilson Observatory, circa 1950.

elements created by the previous generations of stars. This discovery influenced research not only into stellar evolution, but also into the formation and structure of galaxies. Most of Baade's career was spent refining his discoveries and studying other galaxies, such as Andromeda and the Magellanic Clouds, to better understand the processes behind the stars' characteristics.

As we learn about Baade and his life, we also meet other astronomers who worked with Baade. Such names as Hubble, Zwicky, Sandage, and Bok all appear in Baade's life at different times. Included in that list is the book's author, who began working with Baade in the 1950's and was a close friend. I don't know if that friendship influenced how Baade was portrayed, but Baade definitely came off looking better than many of his colleagues. He was described as a great story-teller who inspired many young astronomers both during his presentations at conferences and through informal conversations. Because Baade's position was with the observatory, he didn't have a formal teaching position, but he did serve as a PhD advisor for two students during his time in Pasadena.

Osterbrock's writing style throughout the book was very readable and enjoyable. I will say that he seems to assume a certain level of knowledge of astronomy above the average lay-person. He definitely wrote for a target audience of people who know astronomy and who have heard of Baade. But even an introductory college course in astronomy should be enough to prepare a reader for Walter Baade A Life in Astrophysics. So don't be afraid, you'll enjoy it.

References:

Walter Baade A Life in Astrophysics by Donald E. Osterbrock; Princeton University Press, 2001.

Chapter 5

Space Place

More on this image. See FN6

David Prosper

Find Strange Uranus in Aries

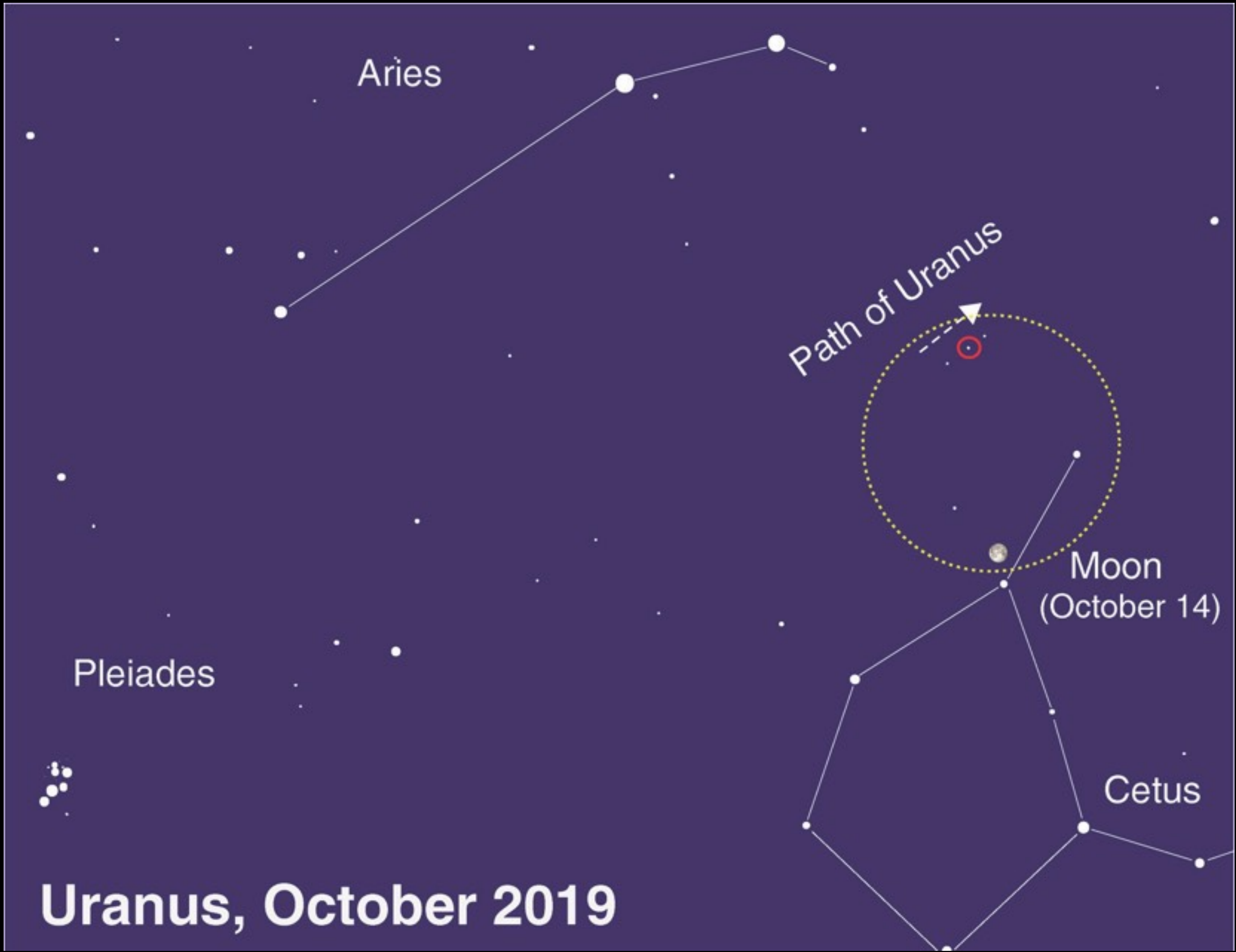
Most of the planets in our Solar System are bright and easily spotted in our night skies. The exceptions are the ice giant planets: Uranus and Neptune. These worlds are so distant and dim that binoculars or telescopes are almost always needed to see them. A great time to search for Uranus is during its opposition on October 28, since the planet is up almost the entire night and at its brightest for the year.

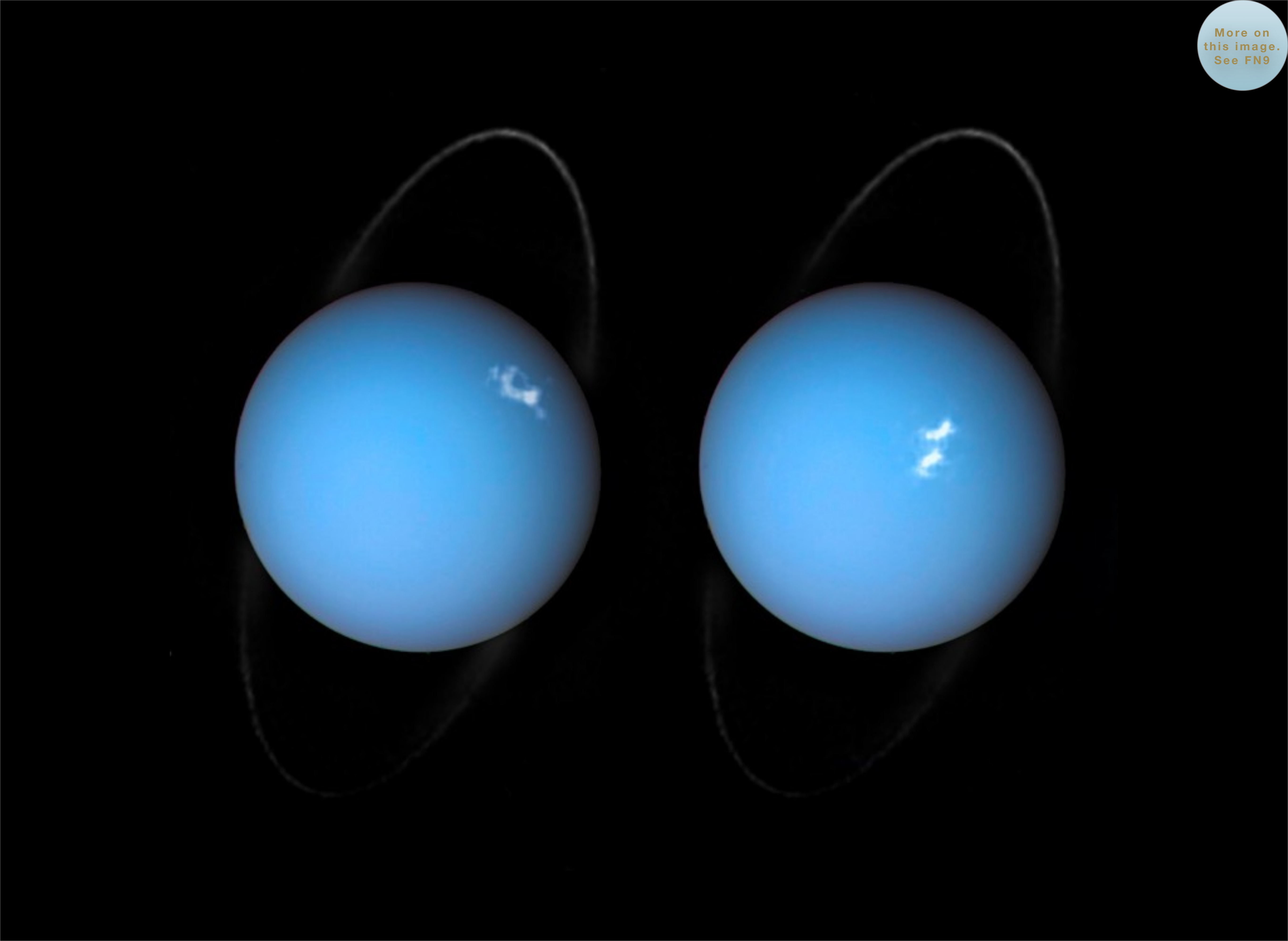
Search for Uranus in the space beneath the stars of Aries the Ram and above Cetus the Whale. These constellations are found west of more prominent Taurus the Bull and Pleiades star cluster. You can also use the Moon as a guide! Uranus will be just a few degrees north of the Moon the night of October 14, close enough to fit both objects into the same binocular field of view. However, it will be much easier to see dim Uranus by moving the bright Moon just out of sight. If you're using a telescope, zoom in as much as possible once you find Uranus; 100x magnification and greater will reveal its small greenish disk, while background stars will remain points.

Try this observing trick from a dark sky location. Find Uranus with your telescope or binoculars, then look with your unaided eyes at the patch of sky where your equipment is aimed. Do you see a faint star where Uranus should be? That's not a star; you're actually seeing Uranus with your naked eye! The ice giant is just bright enough near opposition - magnitude 5.7 - to be visible to observers under clear, dark skies. It's easier to see this ghostly planet unaided after first using an instrument to spot it, sort of like "training wheels" for your eyes. Try this technique with other objects as you observe, and you'll be amazed at what your eyes can pick out.

By the way, you've spotted the first planet discovered in the modern era! William Herschel discovered Uranus via telescope in 1781, and Johan Bode confirmed its status as a planet two years later. NASA's Voyager 2 is the only spacecraft to visit this strange world, with a brief flyby in 1986. It revealed a strange, severely tilted planetary system possessing faint dark rings, dozens of moons, and eerily featureless cloud tops. Subsequent observations of Uranus from powerful telescopes like Hubble and Keck showed its blank face was temporary, as powerful storms were spotted, caused by dramatic seasonal changes during its 84-year orbit. Uranus's wildly variable seasons [possibly] result from a massive collision billions of years ago that tipped the planet to its side.

More on this image. See FN8





More on this image. See FN9

Discover more about NASA's current and future missions of exploration of the distant Solar System and beyond at nasa.gov

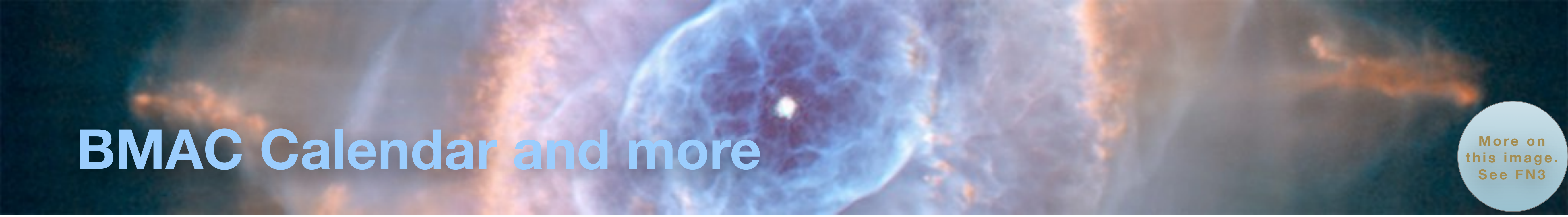
This article is distributed by NASA Night Sky Network . The Night Sky Network program supports astronomy clubs across the USA dedicated to astronomy outreach. Visit nightsky.jpl.nasa.org to find local clubs, events, and more!

Chapter 6

BMAC Calendar and more

More on this image. See FN7

BMAC Calendar and more



Date	Time	Location	Notes
BMAC Meetings			
Friday, October 4, 2019	6 p.m.	Observatory	Program: Observatory Cleaning & Observing. As we wait for dark, we'll have some fun with "The Four Tens." What is that you ask? We'll have four club members talk for just 10 minutes each on an astronomical topic. Our club chair will be contacting four of you to be part of this fun activity. Creativity is part of the short presentation. If the weather is poor, we'll be in the Discovery Theater instead. Please remember to bring cleaning supplies like rags, shop-vac, broom, elbow grease, et al. to help. And, remember, it starts at 6 p.m.; Free.
Friday, November 1, 2019	7 p.m.	Nature Center Discovery Theater	Program: TBA; Free.
Friday, December 6, 2019	7 p.m.	Nature Center Discovery Theater	Program: TBA; Free.
SunWatch			
Every Saturday & Sunday March - October	3-3:30 p.m. if clear	At the dam	View the Sun safely with a white-light view if clear.; Free.
StarWatch			
Oct. 5, 12, 2019	7:30 p.m.	Observatory	View the night sky with large telescopes. If poor weather, an alternate live tour of the night sky will be held in the planetarium theater.; Free.
Oct. 19, 26, Nov. 2, 2019	7 p.m.		
Nov. 9, 16, 23, 30, 2019	6 p.m.		
Special Events			
Oct. 18-20, 2019	-	Bays Mountain Park	StarFest 2019. Our 36th annual astronomy convention/star gathering for the Southeast United States. Three days of astronomy fun, 5 meals, 4 keynote speakers, unique T-shirt, and more. ***Pre-registration by Sept. 27, 2019 with full payment is mandatory for attendance. Sorry, no walk-ins nor "visits."*** Registration is closing shortly.
Monday, November 11, 2019	10 a.m.-1 p.m.	Observatory	Mercury Transit Public Viewing. Come help with using solar telescopes to view the Sun and the planet Mercury transiting across its surface. If poor weather, the event is cancelled.

Bays Mountain Astronomy Club

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Annual Dues:

Dues are supplemented by the Bays Mountain Park Association and volunteerism by the club. As such, our dues can be kept at a very low cost.

$16 /person/year

$6 /additional family member

Note: if you are a Park Association member (which incurs an additional fee), then a 50% reduction in BMAC dues are applied.

The club's website can be found here:

https://www.baysmountain.com/astronomy/astronomy-club/#newsletters

Regular Contributors:

William Troxel

William is the current chair of the club. He enjoys everything to do with astronomy, including sharing this exciting and interesting hobby with anyone that will listen! He has been a member since 2010.

Robin Byrne

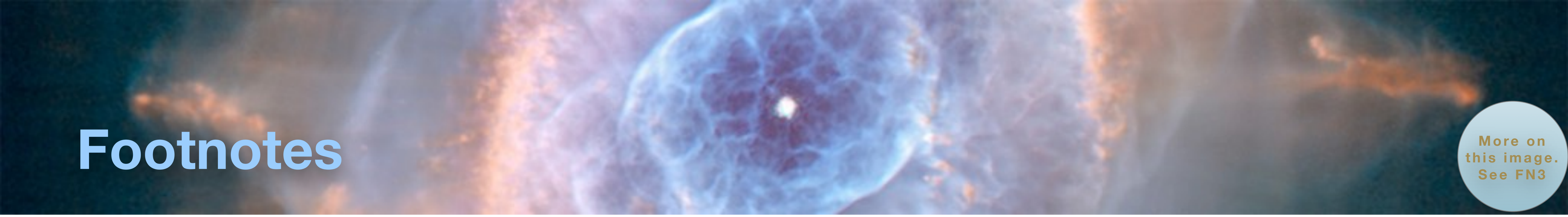
Robin has been writing the science history column since 1992 and was chair in 1997. She is an Associate Professor of Astronomy & Physics at Northeast State Community College (NSCC).

Jason Dorfman

Jason works as a planetarium creative and technical genius at Bays Mountain Park. He has been a member since 2006.

Adam Thanz

Adam has been the Editor for all but a number of months since 1992. He is the Planetarium Director at Bays Mountain Park as well as an astronomy adjunct for NSCC.



Footnotes:

1. The Rite of Spring

Of the countless equinoxes Saturn has seen since the birth of the solar system, this one, captured here in a mosaic of light and dark, is the first witnessed up close by an emissary from Earth … none other than our faithful robotic explorer, Cassini.

Seen from our planet, the view of Saturn's rings during equinox is extremely foreshortened and limited. But in orbit around Saturn, Cassini had no such problems. From 20 degrees above the ring plane, Cassini's wide angle camera shot 75 exposures in succession for this mosaic showing Saturn, its rings, and a few of its moons a day and a half after exact Saturn equinox, when the sun's disk was exactly overhead at the planet's equator.

The novel illumination geometry that accompanies equinox lowers the sun's angle to the ring plane, significantly darkens the rings, and causes out-of-plane structures to look anomalously bright and to cast shadows across the rings. These scenes are possible only during the few months before and after Saturn's equinox which occurs only once in about 15 Earth years. Before and after equinox, Cassini's cameras have spotted not only the predictable shadows of some of Saturn's moons (see PIA11657), but also the shadows of newly revealed vertical structures in the rings themselves (see PIA11665).

Also at equinox, the shadows of the planet's expansive rings are compressed into a single, narrow band cast onto the planet as seen in this mosaic. (For an earlier view of the rings' wide shadows draped high on the northern hemisphere, see PIA09793.)

The images comprising the mosaic, taken over about eight hours, were extensively processed before being joined together. First, each was re-projected into the same viewing geometry and then digitally processed to make the image "joints" seamless and to remove lens flares, radially extended bright artifacts resulting from light being scattered within the camera optics.

At this time so close to equinox, illumination of the rings by sunlight reflected off the planet vastly dominates any meager sunlight falling on the rings. Hence, the half of the rings on the left illuminated by planetshine is, before processing, much brighter than the half of the rings on the right. On the right, it is only the vertically extended parts of the rings that catch any substantial sunlight.

With no enhancement, the rings would be essentially invisible in this mosaic. To improve their visibility, the dark (right) half of the rings has been brightened relative to the brighter (left) half by a factor of three, and then the whole ring system has been brightened by a factor of 20 relative to the planet. So the dark half of the rings is 60 times brighter, and the bright half 20 times brighter, than they would have appeared if the entire system, planet included, could have been captured in a single image.

The moon Janus (179 kilometers, 111 miles across) is on the lower left of this image. Epimetheus (113 kilometers, 70 miles across) appears near the middle bottom. Pandora (81 kilometers, 50 miles across) orbits outside the rings on the right of the image. The small moon Atlas (30 kilometers, 19 miles across) orbits inside the thin F ring on the right of the image. The brightnesses of all the moons, relative to the planet, have been enhanced between 30 and 60 times to make them more easily visible. Other bright specks are background stars. Spokes -- ghostly radial markings on the B ring -- are visible on the right of the image.

This view looks toward the northern side of the rings from about 20 degrees above the ring plane.

The images were taken on Aug. 12, 2009, beginning about 1.25 days after exact equinox, using the red, green and blue spectral filters of the wide angle camera and were combined to create this natural color view. The images were obtained at a distance of approximately 847,000 kilometers (526,000 miles) from Saturn and at a Sun-Saturn-spacecraft, or phase, angle of 74 degrees. Image scale is 50 kilometers (31 miles) per pixel.

The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency and the Italian Space Agency. The Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, manages the mission for NASA's Science Mission Directorate, Washington, D.C. The Cassini orbiter and its two onboard cameras were designed, developed and assembled at JPL. The imaging operations center is based at the Space Science Institute in Boulder, Colo.

For more information about the Cassini-Huygens mission visit http://saturn.jpl.nasa.gov/. The Cassini imaging team homepage is at http://ciclops.org.

Image Credit: NASA/JPL/Space Science Institute

2. Leo Rising

A sky filled with stars and a thin veil of clouds.

Image by Adam Thanz

3. The Cat's Eye Nebula, one of the first planetary nebulae discovered, also has one of the most complex forms known to this kind of nebula. Eleven rings, or shells, of gas make up the Cat's Eye.

Credit: NASA, ESA, HEIC, and The Hubble Heritage Team (STScI/AURA)

Acknowledgment: R. Corradi (Isaac Newton Group of Telescopes, Spain) and Z. Tsvetanov (NASA)

4. Jupiter & Ganymede

NASA's Hubble Space Telescope has caught Jupiter's moon Ganymede playing a game of "peek-a-boo." In this crisp Hubble image, Ganymede is shown just before it ducks behind the giant planet.

Ganymede completes an orbit around Jupiter every seven days. Because Ganymede's orbit is tilted nearly edge-on to Earth, it routinely can be seen passing in front of and disappearing behind its giant host, only to reemerge later.

Composed of rock and ice, Ganymede is the largest moon in our solar system. It is even larger than the planet Mercury. But Ganymede looks like a dirty snowball next to Jupiter, the largest planet in our solar system. Jupiter is so big that only part of its Southern Hemisphere can be seen in this image.

Hubble's view is so sharp that astronomers can see features on Ganymede's surface, most notably the white impact crater, Tros, and its system of rays, bright streaks of material blasted from the crater. Tros and its ray system are roughly the width of Arizona.

The image also shows Jupiter's Great Red Spot, the large eye-shaped feature at upper left. A storm the size of two Earths, the Great Red Spot has been raging for more than 300 years. Hubble's sharp view of the gas giant planet also reveals the texture of the clouds in the Jovian atmosphere as well as various other storms and vortices.

Astronomers use these images to study Jupiter's upper atmosphere. As Ganymede passes behind the giant planet, it reflects sunlight, which then passes through Jupiter's atmosphere. Imprinted on that light is information about the gas giant's atmosphere, which yields clues about the properties of Jupiter's high-altitude haze above the cloud tops.

This color image was made from three images taken on April 9, 2007, with the Wide Field Planetary Camera 2 in red, green, and blue filters. The image shows Jupiter and Ganymede in close to natural colors.

Credit: NASA, ESA, and E. Karkoschka (University of Arizona)

5. 47 Tucanae

In the first attempt to systematically search for "extrasolar" planets far beyond our local stellar neighborhood, astronomers probed the heart of a distant globular star cluster and were surprised to come up with a score of "zero".

To the fascination and puzzlement of planet-searching astronomers, the results offer a sobering counterpoint to the flurry of planet discoveries announced over the previous months.

"This could be the first tantalizing evidence that conditions for planet formation and evolution may be fundamentally different elsewhere in the galaxy," says Mario Livio of the Space Telescope Science Institute (STScI) in Baltimore, MD.

The bold and innovative observation pushed NASA Hubble Space Telescope's capabilities to its limits, simultaneously scanning for small changes in the light from 35,000 stars in the globular star cluster 47 Tucanae, located 15,000 light-years (4 kiloparsecs) away in the southern constellation Tucana.

Hubble researchers caution that the finding must be tempered by the fact that some astronomers always considered the ancient globular cluster an unlikely abode for planets for a variety of reasons. Specifically, the cluster has a deficiency of heavier elements that may be needed for building planets. If this is the case, then planets may have formed later in the universe's evolution, when stars were richer in heavier elements. Correspondingly, life as we know it may have appeared later rather than sooner in the universe.

Another caveat is that Hubble searched for a specific type of planet called a "hot Jupiter," which is considered an oddball among some planet experts. The results do not rule out the possibility that 47 Tucanae could contain normal solar systems like ours, which Hubble could not have detected. But even if that's the case, the "null" result implies there is still something fundamentally different between the way planets are made in our own neighborhood and how they are made in the cluster.

Hubble couldn't directly view the planets, but instead employed a powerful search technique where the telescope measures the slight dimming of a star due to the passage of a planet in front of it, an event called a transit. The planet would have to be a bit larger than Jupiter to block enough light — about one percent — to be measurable by Hubble; Earth-like planets are too small.

However, an outside observer would have to watch our Sun for as long as 12 years before ever having a chance of seeing Jupiter briefly transit the Sun's face. The Hubble observation was capable of only catching those planetary transits that happen every few days. This would happen if the planet were in an orbit less than 1/20 Earth's distance from the Sun, placing it even closer to the star than the scorched planet Mercury — hence the name "hot Jupiter."

Why expect to find such a weird planet in the first place?

Based on radial-velocity surveys from ground-based telescopes, which measure the slight wobble in a star due to the small tug of an unseen companion, astronomers have found nine hot Jupiters in our local stellar neighborhood. Statistically this means one percent of all stars should have such planets. It's estimated that the orbits of 10 percent of these planets are tilted edge-on to Earth and so transit the face of their star.

In 1999, the first observation of a transiting planet was made by ground-based telescopes. The planet, with a 3.5-day period, had previously been detected by radial-velocity surveys, but this was a unique, independent confirmation. In a separate program to study a planet in these revealing circumstances, Ron Gilliland (STScI) and lead investigator Tim Brown (National Center for Atmospheric Research, Boulder, CO) demonstrated Hubble's exquisite ability to do precise photometry — the measurement of brightness and brightness changes in a star's light — by also looking at the planet. The Hubble data were so good they could look for evidence of rings or Earth-sized moons, if they existed.

But to discover new planets by transits, Gilliland had to crowd a lot of stars into Hubble's narrow field of view. The ideal target was the magnificent southern globular star cluster 47 Tucanae, one of the closest clusters to Earth. Within a single Hubble picture Gilliland could observe 35,000 stars at once. Like making a time-lapse movie, he had to take sequential snapshots of the cluster, looking for a telltale dimming of a star and recording any light curve that would be the true signature of a planet.

Based on statistics from a sampling of planets in our local stellar neighborhood, Gilliland and his co-investigators reasoned that 1 out of 1,000 stars in the globular cluster should have planets that transit once every few days. They predicted that Hubble should discover 17 hot Jupiter-class planets.

To catch a planet in a several-day orbit, Gilliland had Hubble's "eagle eye" trained on the cluster for eight consecutive days. The result was the most data-intensive observation ever done by Hubble. STScI archived over 1,300 exposures during the observation. Gilliland and Brown sifted through the results and came up with 100 variable stars, some of them eclipsing binaries where the companion is a star and not a planet. But none of them had the characteristic light curve that would be the signature of an extrasolar planet.

There are a variety of reasons the globular cluster environment may inhibit planet formation. 47 Tucanae is old and so is deficient in the heavier elements, which were formed later in the universe through the nucleosynthesis of heavier elements in the cores of first-generation stars. Planet surveys show that within 100 light-years of the Sun, heavy-element-rich stars are far more likely to harbor a hot Jupiter than heavy-element-poor stars. However, this is a chicken and egg puzzle because some theoreticians say that the heavy-element composition of a star may be enhanced after if it makes Jupiter-like planets and then swallows them as the planet orbit spirals into the star.

The stars are so tightly compacted in the core of the cluster – being separated by 1/100th the distance between our Sun and the next nearest star — that gravitational tidal effects may strip nascent planets from their parent stars. Also, the high stellar density could disturb the subsequent migration of the planet inward, which parks the hot Jupiters close to the star.

Another possibility is that a torrent of ultraviolet light from the earliest and biggest stars, which formed in the cluster billions of years ago may have boiled away fragile embryonic dust disks out of which planets would have formed.

These results will be published in The Astrophysical Journal Letters in December. Follow-up observations are needed to determine whether it is the initial conditions associated with planet birth or subsequent influences on evolution in this heavy-element-poor, crowded environment that led to an absence of planets.

Credits for Hubble image: NASA and Ron Gilliland (Space Telescope Science Institute)

6. Space Place is a fantastic source of scientific educational materials for children of all ages. Visit them at:

http://spaceplace.nasa.gov

7. NGC 3982

Though the universe is chock full of spiral-shaped galaxies, no two look exactly the same. This face-on spiral galaxy, called NGC 3982, is striking for its rich tapestry of star birth, along with its winding arms. The arms are lined with pink star-forming regions of glowing hydrogen, newborn blue star clusters, and obscuring dust lanes that provide the raw material for future generations of stars. The bright nucleus is home to an older population of stars, which grow ever more densely packed toward the center.

NGC 3982 is located about 68 million light-years away in the constellation Ursa Major. The galaxy spans about 30,000 light-years, one-third of the size of our Milky Way galaxy. This color image is composed of exposures taken by the Hubble Space Telescope's Wide Field Planetary Camera 2 (WFPC2), the Advanced Camera for Surveys (ACS), and the Wide Field Camera 3 (WFC3). The observations were taken between March 2000 and October 2009. The rich color range comes from the fact that the galaxy was photographed invisible and near-infrared light. Also used was a filter that isolates hydrogen emission that emanates from bright star-forming regions dotting the spiral arms.

Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

Acknowledgment: A. Riess (STScI)

8. The path of Uranus in October is indicated by an arrow; its position on October 14 is circled. The wide dashed circle approximates the field of view from binoculars or a finderscope. Image created with assistance from Stellarium.

9. Composite images taken of Uranus in 2012 and 2014 by the Hubble Space Telescope, showcasing its rings and aurorae. More at bit.ly/uranusauroras Credit: ESA/Hubble & NASA, L. Lamy / Observatoire de Paris