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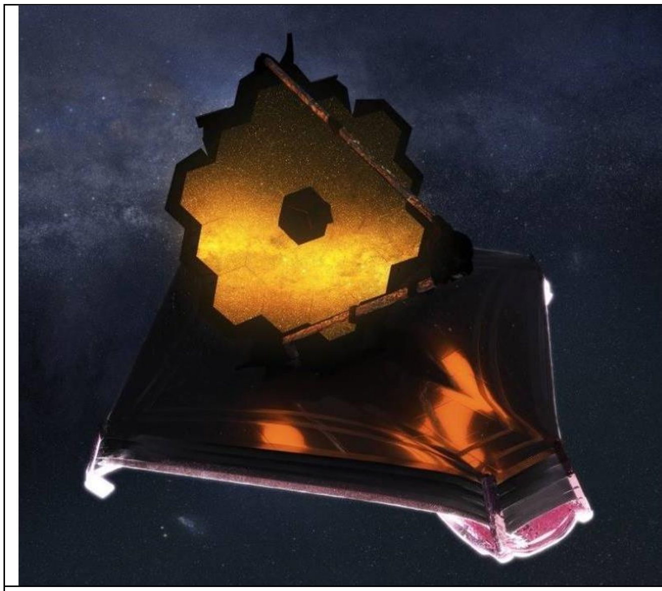
The StarGazer

Newsletter of the Rappahannock Astronomy Club No. 3 Vol. 10 November 2021–January 2022

Where's Webb?

By Linda Billard



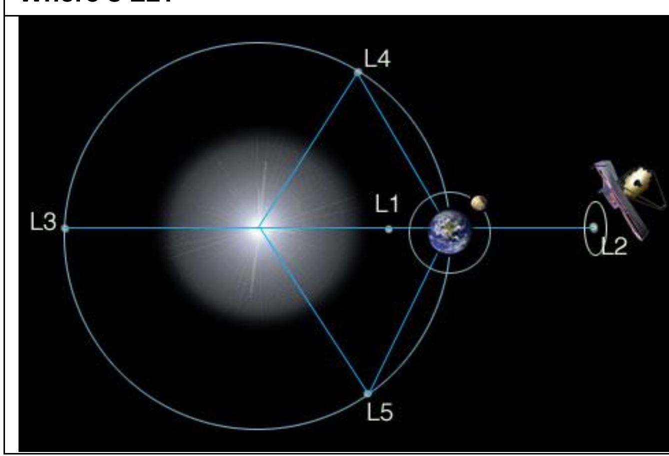
Artist's conception of James Webb Space Telescope in space. Credit: Adriana Manrique Gutierrez, NASA Animator

As you know if you have followed its progress on Where's Webb, the James Webb Space Telescope (JWST) has completed its 29-day journey to its L2 orbit destination, 1 million miles from Earth. After launch early Christmas Day from the European Space Agency (ESA) spaceport in French Guiana, the complicated steps to deploy the telescope began.

The telescope's revolutionary technology will explore every phase of cosmic history, from our solar system to the most distant observable galaxies in the early universe—and everything in between. Webb's mission is to make new and unexpected discoveries and help humanity understand the origins of the universe and our place in it.

On January 4, the JWST team completed deployment of the telescope's gigantic sunshield—the most difficult deployment of the mission. The shield is about the size of a tennis court. At launch, it was folded to fit in the payload area of the Ariane 5 rocket's nose cone. The five-layered sunshield protects the telescope from the light and heat of the Sun, Earth, and Moon. Each layer is plastic as thin as a human hair and coated with reflective metal, giving the telescope an SPF of ~1 million. (Don't imagine it will get a sunburn with this kind of protection.) Together, the five layers reduce exposure from the Sun from more than 200 kilowatts of solar energy to a fraction of a watt—crucial in keeping the telescope's scientific instruments cold enough to allow them to detect the faint infrared light that Webb seeks to observe. ***(Continued on page 4)***

Where's L2?



Joseph-Louis Lagrange, an 18th century mathematician, found the solution to the "three-body problem": Is there a stable configuration in which three bodies could orbit each other yet stay in the same position relative to each other? There are five solutions—the five Lagrange points—named after their discoverer. At Lagrange points, the gravitational pull of two large masses precisely equals the centripetal force required for a small object to move with them. The L1, L2, and L3 points are all in line with each other, and L4 and L5 are at the points of equilateral triangles.

How to Join RAC

RAC, located in the Fredericksburg, Virginia, area, is dedicated to the advancement of public interest in, and knowledge of, the science of astronomy. Members share a common interest in astronomy and related fields as well as a love of observing the night sky.

Membership is open to anyone interested in astronomy, regardless of his/her level of knowledge. Owning a telescope is not a requirement. All you need is a desire to expand your knowledge of astronomy. Most RAC members are from the Fredericksburg area, including, but not limited to, the City of Fredericksburg and the counties of Stafford, Spotsylvania, King George, and Orange. We also have several members who live outside Virginia and have joined to have the opportunity to use the Mark Slade Remote Observatory (MSRO)—one of the benefits of membership.

RAC offers you a great opportunity to learn more about the stars, get advice on equipment purchases, and participate in community events. We meet once a month and hold regular **star parties**. Our website, www.raclub.org is the best source of information on our events.

Options for Dues Payment

RAC annual membership is $20 per family. Student membership is $7.50. You can now pay your dues in two ways. (For reference, the RAC membership year is January–December.) If you join anytime in the last quarter, your membership covers the upcoming year. Astro League dues run July to June.

- **By Mail:** Make out a check to RAC Treasurer and send it to Matthew Scott, RAC Treasurer, PO Box 752, Fredericksburg, VA, 22404-0752. Both new and renewing members should also print out the membership application here, fill it out, and return it with their payment to keep our records up to date.
- ***By PayPal***: You can also pay your dues online. Simply go here, scroll down, and select the appropriate membership type from the dropdown box and click *Pay Now*. You do not need to complete an application because the notification the club receives of your payment will contain all the additional info needed. NOTE: If you pay using PayPal, your actual charge (including the PayPal usage fee) will be: Single/Family $21.23, Student $8.28, Single/Family & AL $29.00, Student & AL $16.05.

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Website: www.raclub.org
Groups.io: Members-only group. When you join RAC, you will receive an invitation to join from the RAC President.

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Jerry Hubbell Astrophotography
Myron Wasiuta Mark Slade Remote Observatory (MSRO)

Upcoming Events*		Recent Events Completed	
Star Party, Caledon State Park	February 26	Star Party, Caledon State Park	November13
Star Party, Caledon State Park	March 5		
Star Party, Caledon State Park	April 2		
Star Party, Caledon State Park	April 30		

*Our Caledon star parties are now public again! However, please check the website raclub.org for updates. To attend a RAC meeting via Zoom, email president@raclub.org for an invitation.

President's Corner

Dear Members,

Beginning in January, RAC's *business* meetings are now at 8 o'clock rather than 7 o'clock. *Presentations* will still begin at 7 o'clock and will be announced in advance. This change is the result of a membership poll conducted last autumn that indicated more members would be able to attend if the meetings were an hour later. In January, I began the Zoom session early, and many members joined and chatted before the business meeting began and continued to chat for nearly an hour after it ended. I will continue to start the Zoom sessions early and let them run for as long as members wish to chat or socialize.

I send Zoom meeting invitations to all RAC members via BCC eMail. Non-members may also participate by sending me a request at president@raclub.org. The invitation specifies the meeting time and whether a presentation is planned.

Just after this month's snowstorm, a circa 1999 Meade 8-inch Schmidt Cassegrain telescope on an LX200 mount was donated to the club or a member. Since the club didn't need it for its loaner equipment inventory, I offered it to club members. Phil Carter and Sabrina Maxwell were both interested, and Sabrina ended up taking it for her school astronomy club. They plan to use it for astrophotography.

Last August, I accepted the donation of a 1984 Celestron Super C8 Plus in near-mint condition from a widow who wanted to give it to someone who would use it. Myron Wasiuta said, "This was the last version of the C8 before go-to mounts made their debut and represents the pinnacle of technology at the time for a commercially available scope designed especially for astrophotography! It was designed from the ground up for deep sky astrophotography." Unfortunately, it's too heavy and complicated to be useful for most people, so I donated it to the MSRO for its outreach program.

May God bless you with transparent skies and excellent seeing.

Glenn Faini
President

Did You Know? by Scott Busby

The era of modern science was ushered in by the publication of a book in 1543 by Nicolaus Copernicus, canon of the cathedral in Frauenburg, Poland. Its title was *De Revolutionibus Orbium Caelestium*. In it he revived the theory of Pythagoras that the sun was the center of the solar system, and skillfully marshalled evidence to support it. Before his book had come back from the printer, Copernicus suffered a stroke. He died without the knowledge of the storm that his book was to evoke or the changes that it was to usher into men's thinking and men's ways of doing things. The storm broke a half century later as a result of the work of three great pioneers of astronomy, Tycho Brahe, Johannes Kepler, and Galileo Galilei.

Source: *The McDonald Telescope, Commemorating the Dedication and the Formal Opening of the McDonald Observatory of the University of Texas May Fifth, 1939*, The Caxton Company Cleveland, The Warner Swasey Company 1939.

Where's Webb?(Continued from page 1)

On January 8, another major milestone was achieved—full deployment of the 21-foot, gold-coated primary mirror, successfully completing all the major deployments to prepare for science operations. The next step was to move Webb's 18 primary mirror segments to align the telescope optics. The ground team commanded 126 actuators on the backsides of the segments to flex each mirror—part of an alignment that will take 5 months to complete. The team will also calibrate the science instruments prior to delivering Webb's first images this summer. (Note: RAC's VP Myron Wasiuta attempted to find and photograph Webb after it reached L2. Read all about it in the article following this one.)

This image of spiral galaxy NGC 1300 combines multiple observations to map stellar populations and gas. Radio light observed by the Atacama Large Millimeter/submillimeter Array (ALMA), represented in yellow, highlight the clouds of cold molecular gas that provide the raw material from which stars form. Data from the Very Large Telescope's Multi Unit Spectroscopic Explorer (MUSE) instrument is represented in red and magenta, capturing the impact of young, massive stars on their surrounding gas. Visible and ultraviolet light captured by the Hubble Space Telescope highlights dust lanes in gold and very young, hot stars in blue. High-resolution infrared images from the JWST will help researchers identify where stars are forming behind the dust and study the earliest stages of star formation in this galaxy. Credits: *science*—NASA, ESA, ESO-Chile, ALMA, NAOJ, NRAO; *image processing*—Alyssa Pagan (STScI)

So, what will the JWST help scientists study? A key question is: how do stars and star clusters form? Until recently, seeking a complete answer was blocked by gas and dust between us and the study subjects. Within the first year of JWST operations, an international team of researchers will complete a highly detailed sketch of the stellar lifecycle using high-resolution infrared-light images of 19 nearby galaxies. More than 100 scientists are part of the multi-wavelength survey program known as PHANGS (Physics at High Angular resolution in Nearby GalaxieS). Their mission is to expand understanding of star formation using Webb's images and share the data and results to drive other research. They are targeting galaxies that can be seen face-on from Earth and are, on average, 50 million light-years away. The new data will also help pinpoint the ages of stellar populations in a diverse sample of galaxies. This will help researchers build more accurate statistical models. With Webb, they will trace the evolutionary sequence of each galaxy's stars and star clusters.

Notably, these Webb observations will become part of a Treasury program—not only available immediately to the public—but of broad and enduring scientific value. The team will work to align Webb's data with complementary datasets from ALMA, MUSE, and Hubble, allowing future researchers to sift through each galaxy and its stellar populations easily, toggling on and off various wavelengths—and zooming into individual pixels of the images. They will provide inventories of different phases of the star-formation cycle, including regions of star formation, young stars, star clusters, and local dust properties.

Webb's location and capabilities allow it to provide data previously impossible to obtain. It opens a new frontier in the mission to explain the formation of the universe.

Sources*: Multiple articles within NASA Goddard Space Flight Center's website at https://www.nasa.gov/goddard*

An Attempt to Image the James Webb Space Telescope Post L2 Insertion From Earth

By Myron Wasiuta
Director-Mark Slade Remote Observatory
mwasiuta@msroscience.org

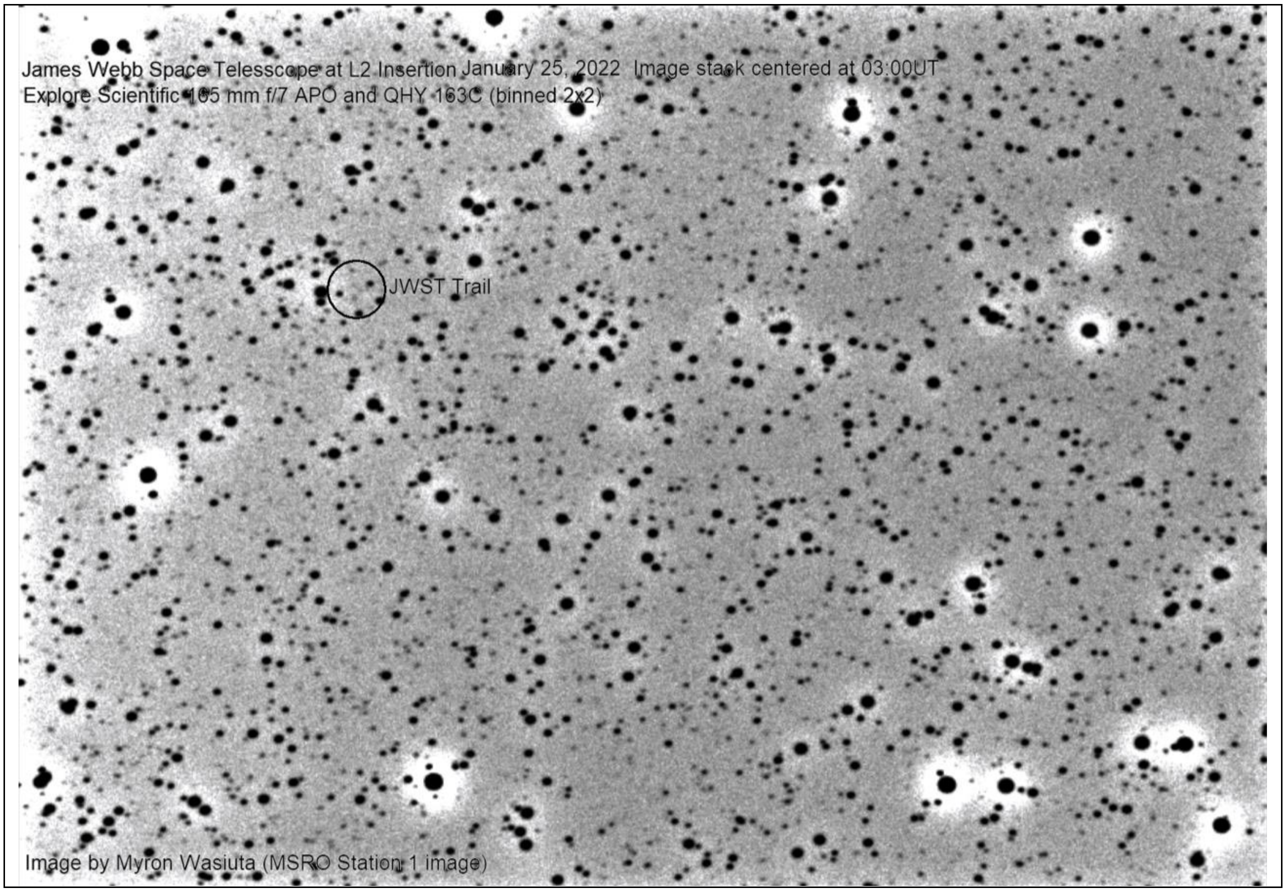
As you read in the previous article, the James Webb Space Telescope (JWST) reached its destination—the L2 Earth-Sun Lagrange point—on Monday, January 24, 2022. At about 930,000 miles in the anti-Sun position, Webb will maintain its position by slowly executing a halo orbit around that point. From there, the telescope will be able to explore the universe without any obstruction from the Earth, Moon, or Sun. It is protected from the intense light and heat of the Sun by a shield of thin reflective layers of Kapton (coated with aluminum and doped-silicon). This makes the shield highly reflective and allows the instruments to cool to their operational temperatures (about –223°C). The instruments on the "cold side" of the JWST are now the process of cooling to their operational temperature.

Using modest telescopes, amateur astronomers have recorded several interesting images of the JWST as it was outbound to its L2 destination. Naturally, when the satellite was closer to Earth, it was brighter and could be readily detected. One particularly interesting gif (2021 December 31—*JWST on the Road to L2-APOD*), made 6 days after launch, shows the telescope streaking past stars in Orion.

However, things are much different now that the telescope is at L2. Because it is so much farther from Earth, it is much fainter. One might think that because its tennis-court sized highly reflective sunshield is fully deployed, it should be relatively bright. This certainly would be the case if the shield were reflecting sunlight directly toward the Earth. However, this will not be the case most of the time. It's more likely the telescope will be tilted such that the sunlight on the shield is reflected in another direction away from our vantage point on Earth. What will be reflecting toward us is the blackness of space itself! This could make the telescope quite faint.

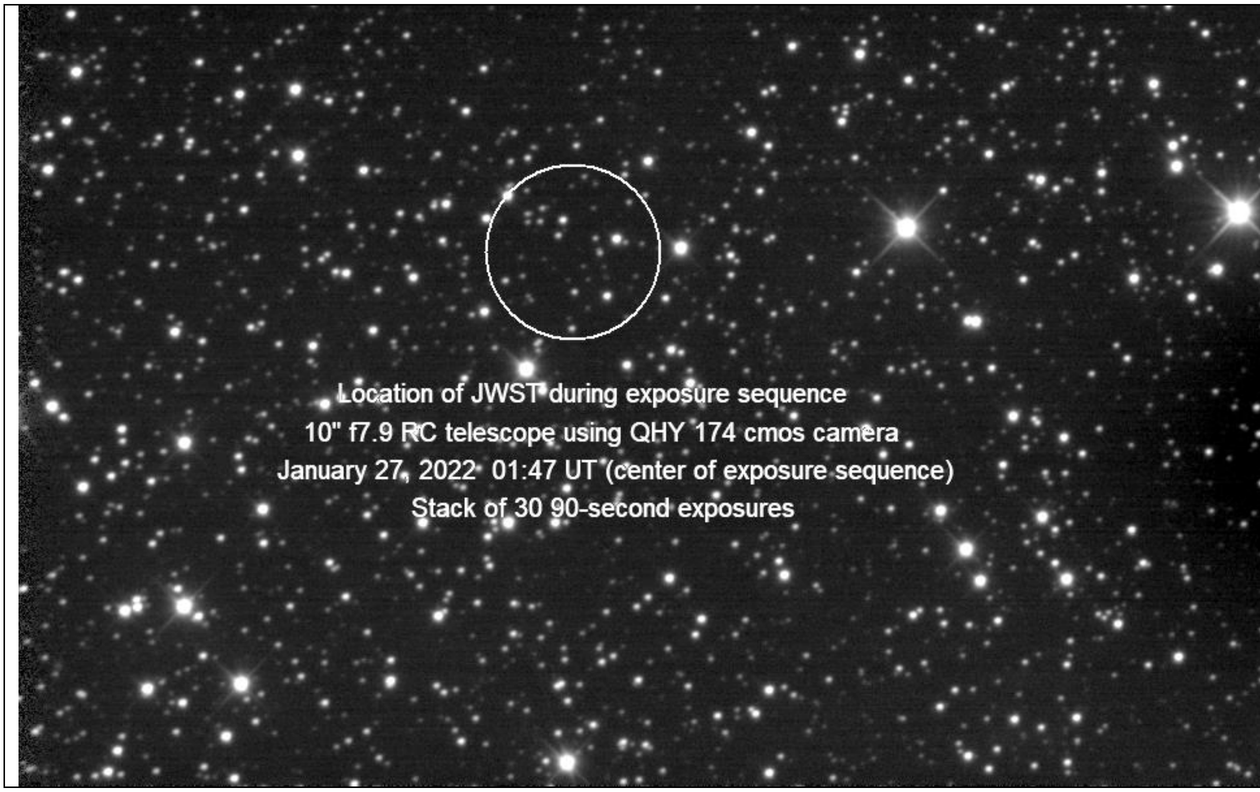
Undaunted by this knowledge and armed with the MSRO StationONE 165mm (6.5-inch) APO refractor and its QHY 163C camera, I set out on the night of January 20 to attempt a series of images. Using the Unistellar website, I generated the sky coordinates for the JWST. Just as I got to the target area, the sky clouded up. No luck. My next opportunity came on the night of January 22. However, clouds came in again, spoiling the effort before I could get enough images. The next night proved equally frustrating—clear skies early—then clouded out just as the target area was acquired.

Finally, on the night of the January 24 about 8 hours after the L2 insertion burn placed the JWST into its final home in deep space, I managed to acquire forty-two 120-second images from StationONE. I was optimistic that something would show up. I stacked the images, expecting to see a trail of the JWST but saw nothing! Next I blinked a set of stacked images taken at the beginning of the session with a stack made from images at the end of the session hoping to see a faint dot jumping back and forth. Nothing. It wasn't until I applied an unsharp mask and harshly processed the images, and then inverted them to show black stars on a white background, that I saw something. I spotted a faint, short trail on the image. Pulling up The Sky live website and generating a map of the sky showing the current location of the JWST, I found that the short trail was in approximately the correct position and was oriented in the proper direction that would have been expected had it been created by the JWST drifting during the imaging session. The only problem was that the trail was so faint and just barely above the floor noise of the individual exposures that it could have been an artifact. My only reason for suspecting it might really be the JWST was that it was in the predicted location and the trail had the proper angular orientation for the JWST as it was moving during the exposure. A rough estimate of its brightness, using the stars in the image, was about 15.



I knew that to get a more definitive detection would require a larger telescope. And it just so happened that a 10" Ritchey-Chretien astrograph was sitting in StationTWO about 100 feet away from StationONE! I felt confident that with the greater light-gathering capability of StationTWO, I would be able to detect the spacecraft. However, I would have to wait two more nights for the next opportunity.

On the very cold night of January 26, 2022, I managed to obtain thirty 90-second exposures of the field where the JWST was drifting among the stars of Monoceros. The night was spectacularly clear, and the telescope performed flawlessly. Images were sharp and showed very faint stars down to 18th magnitude. I stacked the sequence, expecting to see a definite trail. Imagine my surprise when I saw nothing! There was no doubt I was on the target field. It just wasn't there.



At first I was disappointed but then began to think about what that failure really meant. How did it relate to the presumed detection a few nights earlier with a smaller telescope? A clue lies in the APOD time lapse referenced earlier in this article. Careful inspection of it shows the JWST was varying in brightness even as it was coasting outward toward its L2 destination. Note how several of the streaks in that animated gif are decidedly fainter than others—despite being separated by only tens of minutes in time. Could the JWST be a variable object? Of course it could be! With its gigantic sunshield reflecting various parts of the universe our way, sometimes it might catch the Earth, Moon, or sunlight. These specular reflection events would surely make the JWST appear to vary in brightness. So perhaps it's possible the image taken with StationONE is a detection after all. Perhaps the sunshield was oriented such that more light from the Earth, Moon, or near the Sun was aimed directly back at Earth. I will probably never know for sure. But what is certain is that more observations are needed to answer these questions. I would invite RAC members to use the MSRO telescope for this project. It would be a great way to get into remote imaging using a resource available to RAC members. And it would be very interesting as well—perhaps even providing useful scientific data about the most expensive and powerful telescope ever created by humanity!

Astronomy Math—The Next Level (TNL)

By Scott Busby


Courtesy Scott Busby

…Continuing with our Next Level Astronomy Math, we start to increase complexity by working through some extremes.

The nearest star system to ours is Alpha Centauri, which is 4.3 light-years away. Any planet that is as close as 2 light-years from the Sun must therefore be closer to the Sun than to any other star no matter what the plane of its orbit is. It is safely in the Sun's grip. Let's call it the "farthest reasonable planet."

An astronomical unit (A.U.) is equal to about 93 million miles, while a light-year is equal to about 5.86 trillion miles. Therefore, 1 light-year is equal to about 63,000 A.U., and our farthest reasonable planet is about

126,000 A.U. away. Therefore, from Equation 3 (EQ-3 from last newsletter), you can see that the period of the farthest reasonable planet is about 45 million years.

So now, let's ask how close can a planet be to the Sun? Ignoring temperature and gas resistance, suppose that a planet can circle the Sun at its equator, just skimming its surface. For the sake of illustration, let's call it a "surface planet."

The distance of a planet from the Sun is always measured center to center. If you consider the surface planet to be of negligible size, then its distance from the Sun is equal to the radius of the Sun, which is 432,300 miles or 0.00465 A.U. Again, using EQ-3, you can show that the period of such a body is 0.00031 years or 2.73 hours.

What if you wanted to determine how fast a planet is moving, on average, in miles per second (relative to the Sun)? First, you need to figure out how many seconds it takes a planet to make a complete turn in its orbit. You already have the period in years (P). In each year, there are about 31,557,000 seconds. Therefore, the period of the planet in seconds is 31,557,000 P.

Because an astronomical unit is about 93 million miles, the distance of a planet from the Sun in astronomical units (D) is 93,000,000 D. What you need now is the length of the orbit itself. Assuming the orbit is close to an exact circle, its length is equal to its distance from the Sun, multiplied by twice "pi." The value of "pi" is 3.1416, and twice that is 6.2832. If you multiply that by the distance of the planet from the Sun in miles, you get the length of the planetary orbit in miles, which is 584,000,000 D.

To find the average velocity of a planet in miles per second, you must divide the length of the orbit in miles (584,000,000 D) by the duration of its period of revolution in seconds (31,557,000 P). This gives you the value 18.5 D/P—the mean orbital velocity of a planet.

You can simplify this by remembering that, according to Eq-3, $P = \sqrt{D^3}$, so you can write the velocity of a moving planet as 18.5 D/$\sqrt{D^3}$. Since $\sqrt{D^3}$ is equal to $\sqrt{D^2} \times D$ or $D\sqrt{D}$, you can write the velocity of a planet in orbit as equal to $18.5\ D/D\sqrt{D}$ or, in a final simplification (where V stands for velocity):

$$V = 18.5/\sqrt{D} \qquad \text{Eq-5}$$

Remember that D represents the distance of a planet from the Sun in astronomical units. For the Earth, the value of D is equal to 1 and the square root of D is also equal to 1. Therefore, the Earth moves in its orbit at the average rate of 18.5 miles per second.

Because D is known for the other planets, the mean orbital velocity can be calculated without trouble by taking the square root of D and dividing it into 18.5. The results are shown in the following table.

Planet	Mean Orbital Velocity (Miles Per Second)
Mercury	29.8
Venus	21.7
Earth	18.5
Mars	15.0
Jupiter	8.2
Saturn	6.0
Uranus	4.2
Neptune	3.4
Pluto	2.9

If you talk in terms of "Mach numbers," Mach 1 is the equivalent of the speed of sound in the air, Mach 2 to twice that speed, and so on. At 0^{o} C, the speed of sound is 1,090 feet per second, or just about 0.2 miles per second.

Our fastest aircraft move at more than Mach 2, while an astronaut on the International Space Station moves about Mach 25 with respect to the Earth.

Compare this with Pluto, which moves (with respect to the Sun) at a mere Mach 14.5—only half that of the astronaut. The Earth on the other hand, is moving at a respectable Mach 93, and Mercury at a zippy Mach 149.

Looking at extremes again, the farthest reasonable planet, at 126,000 A.U., would have an orbital velocity of just about 0.052 miles per second, or about Mach 0.26. So, even at the distance of 2 light-years, the Sun is still capable of lashing a planet into traveling at one-quarter the speed of sound.

As for the surface planet at the distance of 0.00465 A.U., its orbital velocity must be 271 miles per second, or Mach 1,355. (Incidentally, the fastest conceivable velocity, that of light in a vacuum, is equal to about Mach 930,000, so watch out for anyone who talks casually about Mach 1,000,000. Bet him that Mach 1,000,000 is impossible, and you'll win.)

Source: *Asimov on Astronomy*, Isaac Asimov, Bonanza Books, New York, 1979—Paraphrased except where Asimov quotes other works or examples. In this case, the mathematical problems are described verbatim.

Star Charts—A Fun Accessory From Bygone Days

By Glenn D. Faini

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I enjoy looking at maps and globes. They are a great way to get to know the world. I also enjoy looking at star charts for a similar reason. They are a great way to get to know the sky. Go-to technology makes it so simple to find just about anything in the heavens that people no longer learn to navigate the sky manually. However, there is no better way to learn the night sky than by searching for and finding objects the old-fashioned way.

When I got my first telescope, a Celestron C80 refractor, there were only two ways to find objects to view. If the object was bright enough, I could center it in my finder scope, or Telrad. If not, I had to "star hop." Planispheres were great for finding objects to view with the naked eye, but to star hop, you needed star charts.

The star chart I chose was the *Wil Tirion Sky Atlas 2000.0*, published by Sky Publishing Corporation. There were plenty of others, but this was the one most people in the astronomy club I belonged to at the time recommended. The *Sky Atlas 2000.0* came in three versions, Field Edition, Desk Edition, and Deluxe Edition.

The Field Edition features white stars and deep-sky objects against a black background. The Desk Edition features black stars and objects on a white background. Both were printed on heavy 13.5" x 18.5" paper. The Deluxe Edition features black stars and color-coded deep-sky objects on a white background. The Deluxe Edition charts are 16" x 21", each folded in half and bound in a 12" x 16" format. All three editions of the Sky Atlas were also available laminated for dew protection.

Deluxe Edition

Desk Edition

Field Edition

©Sky Publishing Co.

In 1998, I decided to purchase the Field Edition because I expected to use it mostly out in the field. Soon afterward, I purchased Robert A. Strong's *Sky Atlas 2000.0 Companion*, an index of every Deep Sky Object on the charts to make them easy to find. The Field Edition was the most practical for use in the field, but I always regretted not getting the attractive Deluxe Edition. In 2018, I made Field of View indicators for my 7x and 12x binoculars and my Nikon D3300/NexStar 102SLT. These really help get a feel for what I should expect to see.

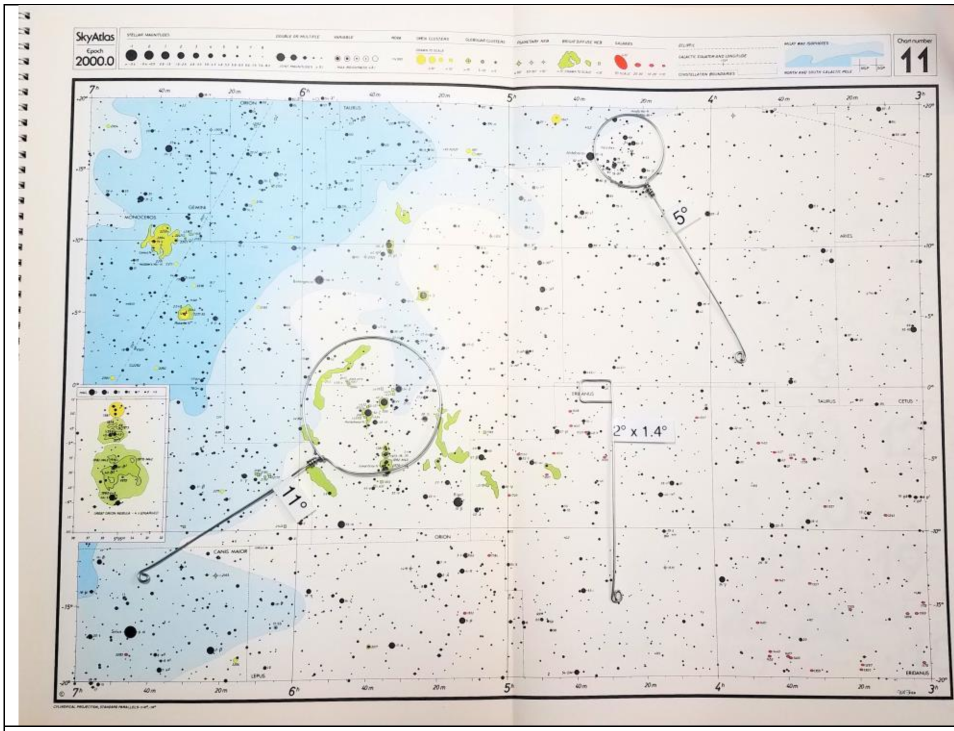


Photo of Field of View Indicators by Glenn D. Faini

Unfortunately, owing to the popularity of go-to telescopes, sky charts are not as popular as they were, and *Sky Atlas 2000.0* has been out of print for a number of years. However, in 2021, I was pleased to obtain pristine copies of both the Desk and Deluxe editions since now, I mostly use the charts on my desk for planning purposes. Thanks to go-to mounts and mobile device apps, I never use paper charts out in the field anymore. Seeing a group of astronomers bending over plastic-covered paper charts with red flashlights planning their next star hop is a thing of the past.

Comet Leonard: Here and Gone Forever

By Linda Billard

Myron Wasiuta's beautiful image of comet C/2021 A1 Leonard (see Image of the Quarter at the end of this newsletter) is a wonderful souvenir of an ephemeral object. It was discovered just a year ago by Gregory Leonard. Leonard spotted it in images taken from the Mt. Lemmon Observatory in Arizona in connection with his participation in the Catalina Sky Survey (CSS). CSS is a NASA-funded project supported by the Near Earth Object (NEO) Observation Program. Based at the University of Arizona's Lunar and Planetary Lab in Tucson, CSS's mission is to discover and track NEOs to catalog at least 90 percent of the estimated population of NEOs larger than 140 meters. Some of these classify as potentially hazardous asteroids, which pose an impact threat to Earth. The longstanding success of the project can be attributed to the team's comprehensive sky coverage and inclusion of near real-time human attention to the NEO discovery and follow-up process.

Greg Leonard's journey to his current role at CSS was not a direct route. It more or less began where you might expect, fulfilling a US Geological Survey (USGS) postgraduate internship working with Eugene and Carolyn Shoemaker and David Levy in the early 1990s at the Palomar Asteroid and Comet Survey. However, when that internship ended, Leonard went back to field geology, working for the mineral industry all over the world. However, during that 15-year period and a subsequent stint in the field of glaciology, he never lost interest in planetary science, continuing to work on the odd planetary project with his former colleagues at USGS and the Planetary Science Institute. A couple years after a chance encounter with astronomer Rik Hill, Leonard applied for a position at CSS and coincidentally found himself replacing Hill, who was retiring as an observer with the program.

Comet C/2021 A1 (Leonard), one of four discovery images (circled in pink). Credits: Catalina Sky Survey; Images: G. Leonard.

Fast forward to early 2021. At the time of discovery, comet Leonard was 400,000 times dimmer than the human eye can see. Leonard saw it as a fuzzy patch of pixels tracking across the background stars in four telescope images. (Photo at left is the first. To see an animation of all four photos, go here.) Because their orbits are at large heliocentric distances in the most frigid regions of space, most comets have remained essentially untouched since the beginning of the Solar System. Consequently, their centers contain grains and gas from the protosolar nebula in which they formed, and thus they provide a window into the early conditions of the Solar System's formation.

Comet Leonard reached its closest approach to the Sun (perihelion) on January 3, 2022. Unfortunately, during the time of closest approach, it was predicted to be a challenging object to view because it would hover low above the west-southwest horizon just after the Sun sets. However, CSS astronomers had predicted that around December 5 –10, the comet would be in the early morning eastern sky and could be viewed with binoculars and telescopes, preferably away from bright urban lights. Myron's image is the perfect example of what was possible.

Highlights of Recent RAClub Presentations

Abstracted from Bart Billard's Meeting Minutes
NOTE: There were no presentations in November or January. A synopsis of the December presentation is below.

December 2021—Galaxies

This sweeping bird's-eye view of a portion of the Andromeda galaxy (M31) is the sharpest image ever taken of our galactic next-door neighbor. Credits: NASA, ESA, J. Dalcanton, B.F. Williams, and L.C. Johnson (University of Washington), the PHAT team, and R. Gendler

David Eicher, editor of *Astronomy Magazine*, joined the RAC meeting on Zoom to talk about galaxies. He said Timothy Ferris's 1980 book on the subject was his current favorite. He said he was amazed at how nearly everything we knew about galaxies has changed in the last 40 years and especially the last 10 years. He began with Edwin Hubble in October 1923 observing what was called the Andromeda Nebula, M31, and discovering a cepheid variable star so faint that it indicated the Andromeda Nebula was three times farther away than the largest estimate anyone else had made for the size of the entire universe at the time. What astronomers called "spiral nebulae" were then shown to be separate galaxies like the Milky Way. Soon red shifts studied by V.M. Slipher (starting before Hubble's discovery) were tied to a new distance scale that revealed the expansion of the universe.

For studying galaxies (or any new phenomenon), the first step was classification, which Hubble pursued in the 1930s. He developed the "tuning fork" diagram, which Gerard de Valcouleurs expanded in the 1950s and 1960s to the system still in use today. David explained that estimates of the number of galaxies in the universe were complicated by the relationship between the distance of observed objects and the amount of time that passed before the light observed arrived here. Galaxies grow by mergers of smaller galaxies, and he suggested galaxies of the early universe, represented by the most distant galaxies we see, numbered in the trillions, whereas the number of galaxies of the current universe, like those seen nearby, was probably 100 billion. He deferred talking about how that estimate was made to later in the presentation.

David said that a good way to start to understand galaxies is to begin at home with the Milky Way. It has some 400 billion stars, a number he said was rather uncertain because the most abundant stars are hard-to-see red dwarfs. David described the location of our solar system as at the edge of a spiral arm known as the Orion arm—about 26,000 light years from the center of the galaxy. He indicated it was a good thing it was far out because in the centers of galaxies is a lot of danger. He showed a Spitzer image in the direction of the center of our galaxy, which he said was in Sagittarius just about at the midpoint of a line between the cluster M6 and the Lagoon Nebula. He noted that we see only a quarter of the way to the actual center, mostly because of dust between the us and the center. There is a relatively modest black hole there of about 4.3 million times the mass of the Sun.

A next step beyond our Milky Way, David said, were galaxies of our Local Group (named in the 1930s by Hubble). It included at least 55 galaxies. Again, the number was uncertain because, as with stars, dwarf galaxies are the most common, and the number of dwarf galaxies was uncertain. He said the three largest galaxies were the Andromeda galaxy (M31), the Milky Way, and the Triangulum galaxy (M33). The rest of the local group were dwarf galaxies. He showed images of M31, with its two dwarf galaxy satellites (M32 and NGC205) and M33 with faint surface brightness. He noted M33 had one of the largest known star-forming regions (NGC604) and lacked a central black hole (although most galaxies have been found to have them).

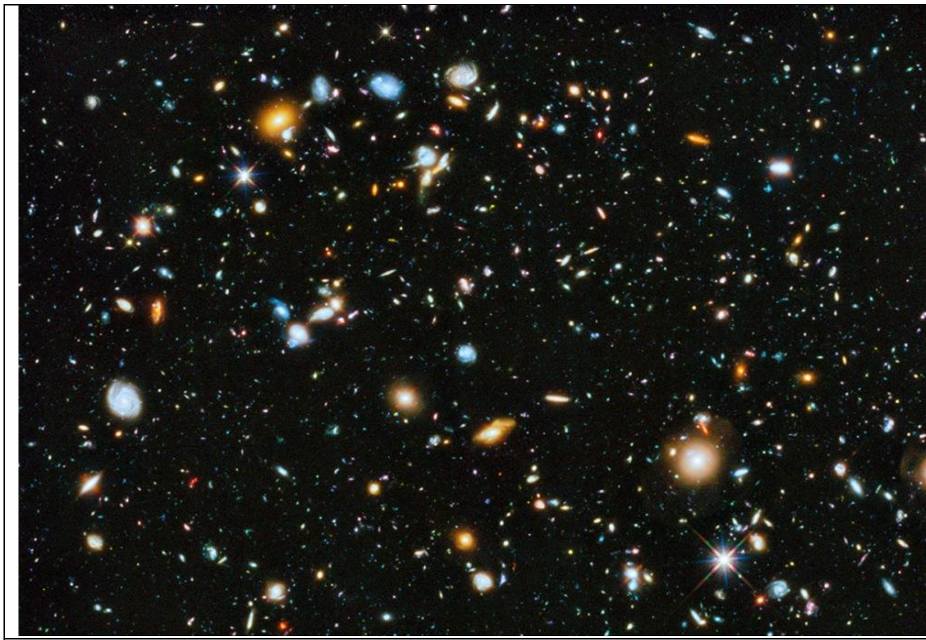
The Antennae galaxies. *Image Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration*

David showed the Antennae galaxies and NGC 2623, examples of merging galaxies. Although generally there is a lot of room between galaxies, there are plenty of examples of merging galaxies for us to observe. He said the Milky Way disk was an estimated 8 billion years old, and that it had probably started with the merger of about 100 small galaxies. He also noted the predicted merger of the Milky Way and Andromeda in about 5 billion years, and said that Avi Loeb, an astronomer at Harvard who had studied and written about the motion of Andromeda, proposed "Milkomeda" as the name for it.

Continuing beyond the Local Group, David discussed the Virgo Cluster, which contains M87, its most massive giant elliptical galaxy. The image he showed had a hint of the jet in M87. The M87 black hole— or to be more exact its shadow—was the first Event Horizon image. Its mass was 3.5 billion solar masses. He said M87 had about 12,000 globular clusters, compared with a couple of hundred for the Milky Way. The M87 image that he used was one taken by the amateur astronomer Adam Block.

David continued with examples of more exotic galaxies. He showed an example of “Einstein’s cross” in which four images of a distant quasar exactly behind the center of a faint galaxy were formed by its gravitational lensing effect. He also showed a recent Hubble image, the Hubble Ultra Deep Field, explaining that based on the size of the tiny patch of sky it imaged and the number of galaxies it showed, there were probably 100 billion galaxies in the visible universe.

Quasars and various active galaxies were puzzles for a long time but were more recently seen as active centers of distant galaxies with central black holes consuming matter and radiating toward us. David said that by the 1980s, astronomers were finding that most galaxies had central black holes. When galaxies merged, the disturbances caused matter to fall into their black holes with some heated and ejected in jets of matter and energy, so the appearance depended on the viewing angle. Sometime after these mergers, conditions would quiet again. Thus, nearby galaxies were mostly quiet while distant galaxies seen as they were billions of years ago were more often active.


Hubble Ultra Deep Field 2014. Credit: NASA, ESA, H. Teplitz and M. Rafelski (IPAC/Caltech), A. Koekemoer (STScI), R. Windhorst(ASU), Z. Levay (STScI)

Continuing with the subject of mergers, David showed an image of Perseus A (NGC1275), a monstrous centrally dominant galaxy. It had evidence of chaotic disturbances and widespread star-forming activity, all attributed to an active central black hole. He described the puzzle of how elliptical galaxies formed. Effects of angular momentum suggested that like planetary systems, galaxies should have spiral or disk shapes. Astronomers eventually realized mergers could explain the elliptical shapes. He showed an image of Centaurus A (NGC5728) and suggested maybe after their merger, the Milky Way and Andromeda might resemble it.

David said that cosmic inflation implied the universe could be much larger than what was visible, perhaps infinite. Considering only the visible universe, which includes some 10,000 billion billion stars and is 93 billion light years in diameter, he discussed the possibility of life elsewhere. He said exoplanet searches recently showed planetary systems to be common, and spectroscopy showed chemistry is consistent throughout the cosmos. Materials that made life possible here were abundant. The amino acid glycine was found in the first comet sample returned to Earth in 2016. He pointed out the possibility life started somewhere else was not unreasonable, but that the cosmic distance scale that Hubble found made it unlikely we would see aliens land and greet us. If the astronomical unit measuring the distance from the Sun to Earth were one centimeter, the inside edge of the Oort Cloud would be 10 football fields, and Proxima Centauri, the nearest star, would be four times that. He also noted the energy requirements to move material objects (as opposed to light with no rest mass) over interstellar distances made it likely SETI was the only method that might answer the question about life elsewhere.

David concluded with discussion of a very new area of research on galaxies, suggesting the possibility of zones where life is more likely to exist. Rocky worlds require “metal-rich” stars. If that is the case, a galaxy like the Milky Way may have a “habitable zone” in the spiral arms, about 10,000 to 30,000 light years from the center. Farther out may mean fewer “metals” and farther in may mean much greater danger. David concluded that 100 years after Hubble and with all we have learned, especially in the last 15 years, we still have a lot to learn about galaxies.

After thanking David Eicher, Glenn Faini mentioned the Rappahannock Astronomy Club was originally named for M33, the Triangulum Astronomy Club. David thought he might actually remember that name from club newsletters they used to get. He later mentioned an interest in visiting this area for its Civil War history. They also discussed the comparison between Hubble's M31 image and modern images. Amateur astronomers' images today made the 1950s television show Lost in Space look like it used Hubble's image. Bart Billard asked David to comment on the red shift of the distant blue galaxies he had pointed out in the Hubble Ultra Deep Field image. He confirmed they were greatly red shifted, but we did not yet know much about them or how they formed so long ago. Addressing this question was one of the goals of the James Webb Space Telescope due to be launched soon.

Image of the Quarter: Comet Leonard

By Myron Wasiuta

Myron made this image in the early morning on December 5, 2021, using StationTHREE of the MSRO. He said:

"…I took [this shot] using a 102mm f/7 APO and QHY 178C camera. The telescope was autoguided on stars, and then the comet images manually stacked in Maxim DL. Th[is] image, showing the background stars, was created by stacking a short 5-minute exposure of the comet with a stack of forty-five 60-second subframes centered on the comet nucleus using software (Maxim DL) to align."