Volume 50 Number 6 June 2024

The Celestial Mechanic

The Official Newsletter of the Astronomy Associates of Lawrence

Coming Events

Monthly Meeting
June 23, 2024, 7:00PM
Baker Wetlands Discovery Center

Public Observing
June 23, 2024, 8:00PM
Baker Wetlands Discovery Center

Club Officers
President
Rick Heschmeyer email

AICOR
William Winkler email

NSN Coordinator
Howard Edin email

Faculty Advisor
Dr. Jennifer Delgado email.

Newsletter Editor
Chuck Wehner email

Inside This Issue

Report From the Officers

By Rick Heschmeyer

On Saturday, May 18th Baker Wetlands Discovery Center hosted their annual Family Fun Day. Due to an emergency, we had to cancel out participation in this event as well as the Astronomy Day observing event that was scheduled for that evening. Special thanks to AAL members Jerelyn and Paul Ramirez for setting up am astronomy table at the Family Fun Days and entertaining Discovery Center guests. Once a new date has been scheduled for the Public Observing event it will be shared with the club.

This year's ALCON Convention will take place in Kansas City from July 17-20 and will be hosted by the Astronomical Society of Kansas City. There are some great speakers and daily convention activities lined up as well as evening events at Gottlieb Planetarium, Linda Hall Library, and Powell Observatory. If you would like more information or to register for ALCON, visit the website at alcon2024.org.

The Lawrence City Band Summer Concert Series is upon us. The Astronomy Associates of Lawrence will be conducting post-concert observing in South Park following the concerts scheduled for these dates:

June 12, June 26, July 10

Observing will start around 9 PM as the concert is concluding and will last as long as people are present (weather permitting, of course). Hope to see you there.

Hubble Goes Hunting for Small Main Belt Asteroids

HUBBLESITE, APRIL 18, 2024

Like boulders, rocks, and pebbles scattered across a landscape, asteroids come in a wide range of sizes. Cataloging asteroids in space is tricky because they are faint and they don't stop to be photographed as they zip along their orbits around the Sun.

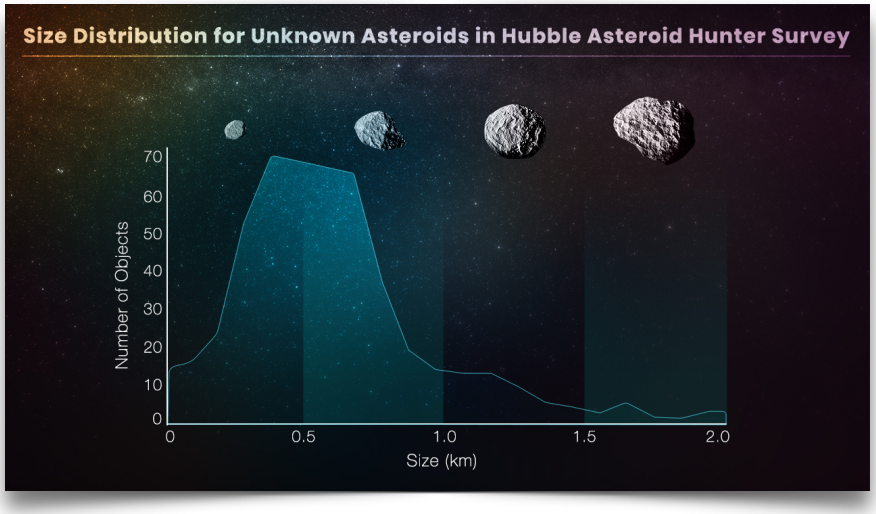
Astronomers recently used a trove of archived images taken by NASA's Hubble Space Telescope to visually snag a largely unseen population of smaller asteroids in their tracks. The treasure hunt required perusing 37,000 Hubble images spanning 19 years. The payoff was finding 1,701 asteroid trails, with 1,031 of the asteroids previously uncatalogued. About 400 of these uncatalogued asteroids are below 1 kilometer in size.

Volunteers from around the world known as "citizen scientists" contributed to the identification of this asteroid bounty. Professional scientists combined the volunteers' efforts with machine learning algorithm to identify the asteroids. It represents a new approach to finding asteroids in astronomical archives spanning decades, which may be effectively applied to other datasets, say the researchers.

"We are getting deeper into seeing the smaller population of main belt asteroids. We were surprised with seeing such a large number of candidate objects," said lead author Pablo García Martín of the Autonomous University of Madrid, Spain. "There was some hint of this population existing, but now we are confirming it with a random asteroid population sample obtained using the whole Hubble archive. This is important for providing insights into the evolutionary models of our solar system."

The large, random sample offers new insights into the formation and evolution of the asteroid belt. Finding a lot of small asteroids favors the idea that they are fragments of larger asteroids that have collided and broken apart, like smashed pottery. This is a grinding-down process spanning billions of years.

An alternative theory for the existence of smaller fragments is that they formed that way billions of years ago. But there is no conceivable mechanism that would keep them from snowballing up to larger sizes as they agglomerated dust from the planet-forming circumstellar disk around our Sun. "Collisions would have a certain signature that we can use to test the current main belt population," said co-author Bruno Merín of the European Space Astronomy Centre, in Madrid, Spain.



Amateur Astronomers Teach AI to Find Asteroids

Because of Hubble's fast orbit around the Earth, it can capture wandering asteroids through their telltale trails in the Hubble exposures. As viewed from an Earth-based telescope, an asteroid leaves a streak across the picture. Asteroids "photobomb" Hubble exposures by appearing as unmistakable, curved trails in Hubble photographs.

As Hubble moves around the Earth, it changes its point of view while observing an asteroid, which also moves along its own orbit. By knowing the position of Hubble during the observation and measuring the curvature of the streaks, scientists can determine the distances to the asteroids and estimate the shapes of their orbits.

The asteroids snagged mostly dwell in the main belt, which lies between the orbits of Mars and Jupiter. Their brightness is measured by Hubble's sensitive cameras. And comparing their brightness to their distance allows for a size estimate. The faintest asteroids in the survey are roughly one forty-millionth the brightness of the faintest star that can be seen by the human eye.

"Asteroid positions change with time, and therefore you cannot find them just by entering coordinates, because at different times, they might not be there," said Merín. "As astronomers we don't have time to go looking through all the asteroid images. So we got the idea to collaborate with over 10,000 citizen-science volunteers to peruse the huge Hubble archives."

In 2019 an international group of astronomers launched the Hubble Asteroid Hunter, a citizen-science project to identify asteroids in archival Hubble data. The initiative was developed by researchers and engineers at the European Science and Technology Centre (ESTEC) and the European Space Astronomy Centre's science data center (ESDC), in collaboration with the Zooniverse platform, the world's largest and most popular citizen-science platform, and Google.

A total of 11,482 citizen-science volunteers, who provided nearly 2 million identifications, were then given a training set for an automated algorithm to identify asteroids based on artificial intelligence. This pioneering approach may be effectively applied to other datasets.

The project will next explore the streaks of previously unknown asteroids to characterize their orbits and study their properties, such as rotation periods. Because most of these asteroid streaks were captured by Hubble many years ago, it is not possible to follow them up now to determine their orbits. ☀

Night Sky Notes: Stargazing for Beginners

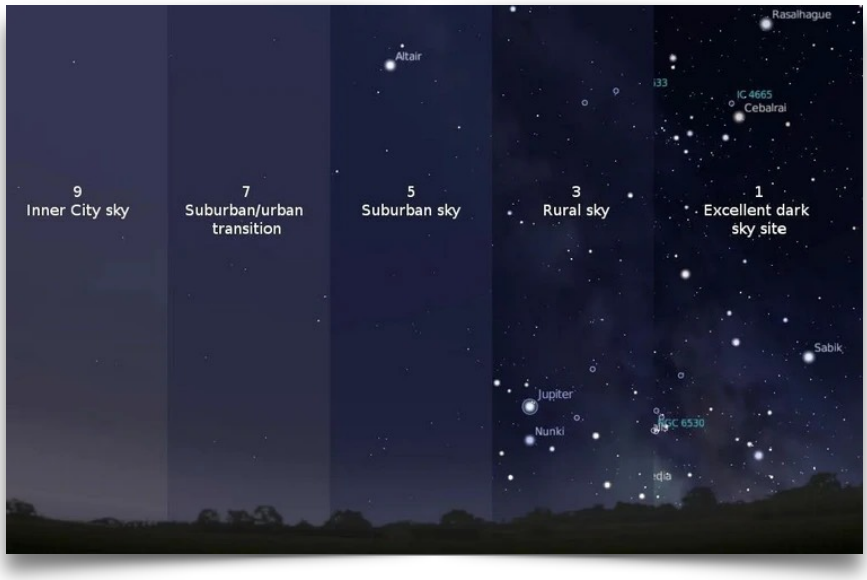
By Kat Troche

NIGHTSKY, MAY 2024

Millions were able to experience the solar eclipse on April 8, 2024, inspiring folks to become amateur astronomers – hooray! Now that you've been 'bitten by the bug', and you've decided to join your local astronomy club, here are some stargazing tips!

The Bortle Scale

Before you can stargaze, you'll want to find a site with dark skies. It's helpful learn what your Bortle scale is. But what is the Bortle scale? The Bortle scale is a numeric scale from 1-9, with 1 being darkest and 9 being extremely light polluted; that rates your night sky's darkness. For example, New York City would be a Bortle 9, whereas Cherry Springs State Park in Pennsylvania is a Bortle 2.



Determining the Bortle scale of your night sky will help narrow down what you can expect to see after sunset. Of course, other factors such as weather (clouds namely) will impact seeing conditions, so plan ahead. Find Bortle ratings near you here: www.lightpollutionmap.info

No Equipment? No Problem!

There's plenty to see with your eyes alone. Get familiar with the night sky by studying star maps in books, or with a planisphere. These are great to begin identifying the overall shapes of constellations, and what is visible during various months. ☀

Biggest Solar Storm in Decades Triggers Intense Auroras: The Science Explained

By Michelle Starr

SCIENCEALERT, MAY 13, 2024

For the last few nights, Earth has been bathed in green and red light that shimmers across the skies – and more is on the way.

That's because we've been buffeted by solar storms, as huge outflows of material that exploded from the Sun slam into our magnetic field.

This is not an uncommon occurrence, but what makes these current solar (or geomagnetic) storms so noteworthy is their remarkable power. We haven't seen a solar disruption this big since the Great Halloween Solar Storms of 2003.

Although such a huge event has the potential to make a bit of a mess on Earth, we appear to have escaped more or less unscathed so far.

The result: absolutely jaw-dropping auroras that dance across Earth's skies, to latitudes far lower than are usually treated to these wondrous spectacles.

For several nights in a row, these conditions have persisted, producing two G5-level geomagnetic storms. These are labeled as "extreme", the most powerful class of solar storms that wrack our planet. And they can be dangerous.

The Great Halloween Storms produced power grid fluctuations across North America, a power outage in Sweden, and destroyed 12 power station transformers in South Africa.

The current solar storms have not, as far as we know, produced any damage, although power grid irregularities have been reported. With the storms waning in intensity, so too is the threat of danger; but more solar storms could be looming in the near future.

The culprit is a sunspot region named AR 3664 that's currently crossing the face of the Sun. This huge region is visible without a telescope, if you still have your eclipse glasses kicking around – do NOT look directly at the Sun without eye protection.

It's also extremely active, having spat out several X-class flares, the most powerful flares of which our Sun is capable. But flares alone don't have this much of an effect on Earth. The big guns here are the coronal mass ejections (CME) that sometimes occur in concert with flares, released from sunspot regions where solar magnetic field reconnections cause huge bursts of energy.

CMEs are massive expulsions of plasma and magnetic fields that are ejected from the Sun out into the Solar System, in the range of billions of tons. And they really are something to behold.

It can take a few days to reach Earth, but when a CME smacks into our planet's magnetic field, it makes a bit of a ruckus. The particles in the CME get accelerated along Earth's magnetic field lines until they are dumped out into our atmosphere, where they interact with particles that are already there.

One part of this is the aurora. You might think of this as primarily green, and you're not wrong. But when an aurora is particularly energetic, we get to see huge walls of red glow lighting up the sky. This has to do with particles involved and the altitude at which they are interacting.

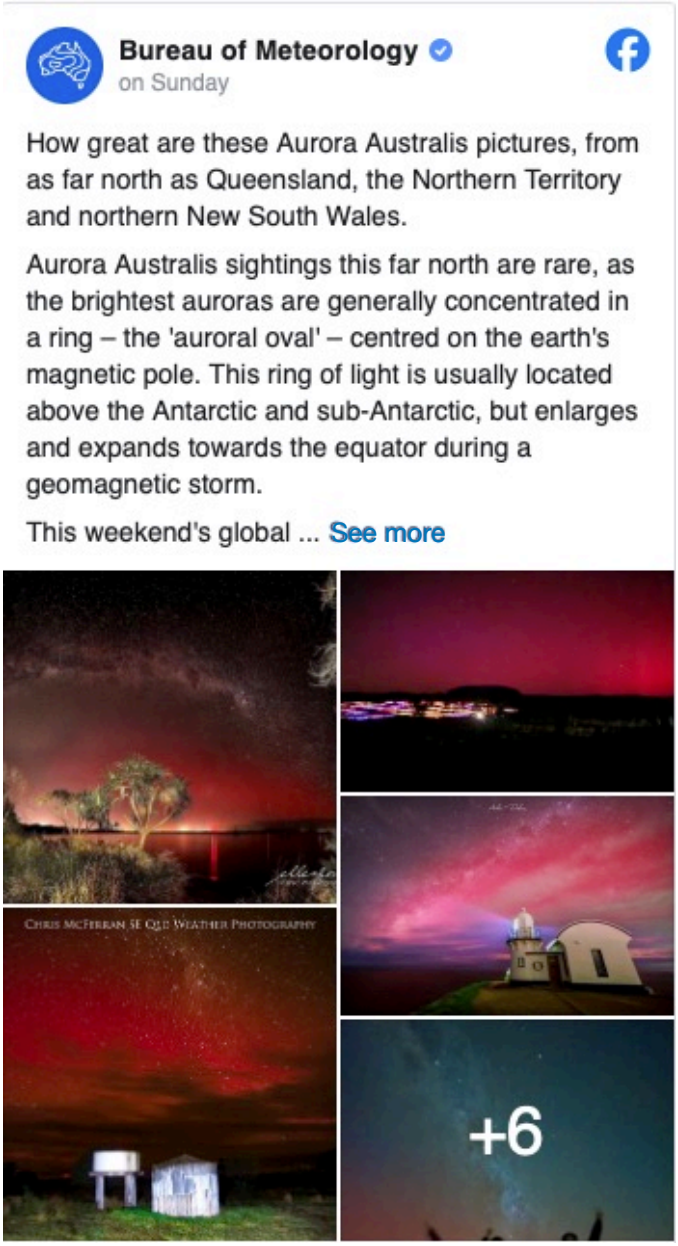
Green aurora is caused by solar particles interacting with oxygen at altitudes between 100 and 300 kilometers (62 to 186 miles). But the brilliant scarlet light we've been seeing is the result of interaction with oxygen at higher altitudes, between 300 and 400 kilometers. And they have to be at least 10 times as bright as green auroras to be seen with the naked eye.

Other effects of the solar storm include the aforementioned power grid anomalies, which are the result of currents generated by atmospheric particle interactions. These currents create surges in the power grids that can cause damage. And satellites and high-frequency radio communications can be disrupted, although most people won't notice this.

AR 3664 is, at time of writing, about to disappear behind the disk of the Sun, but its rowdiness could continue. It's just spat out another X-class flare, and although it's no longer pointed in our direction, any

CMEs could send particles out to contribute to ongoing solar storms.

The NOAA is predicting moderate geomagnetic storms until 02:00 UTC on 13 May. But with the Sun about to (or in the midst of) hit the peak of its 11-year



activity cycle, don't be surprised if more sunspot regions start showing us a good time.

You can track whether you're likely to see auroras on the NOAA's Space Weather Prediction Center website for the northern hemisphere, and the Australian Bureau of Meteorology's Space Weather Forecasting Centre for the south. ☀

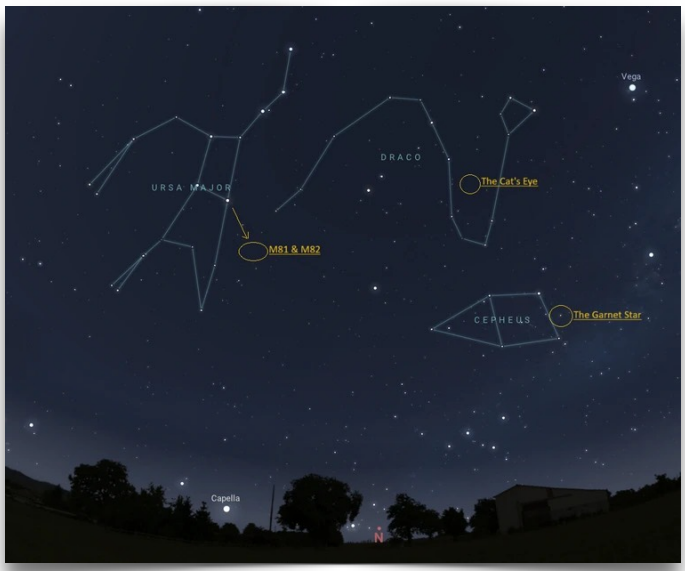
Constant Companions: Circumpolar Constellations, Part III

By Kat Troche

Nightskynetwork, June 2024

In our final installment of the stars around the North Star, we look ahead to the summer months, where depending on your latitude, the items in these circumpolar constellations are nice and high.

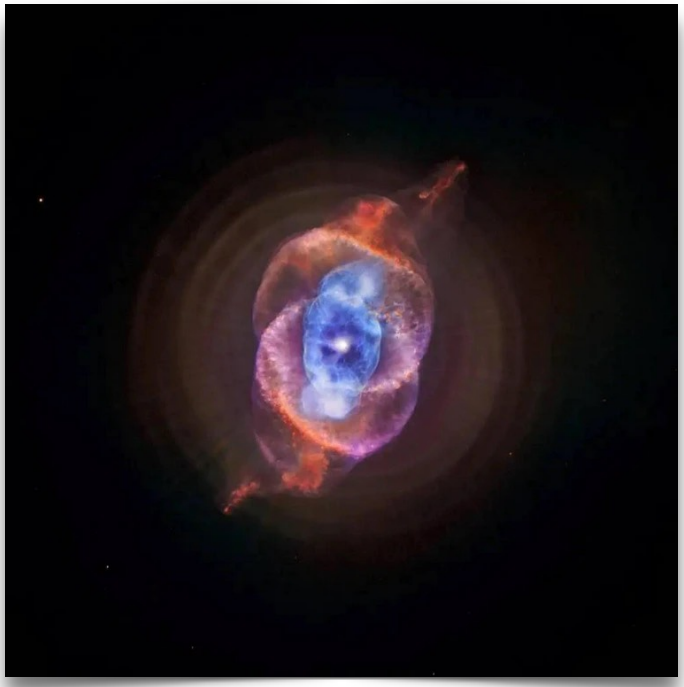
Today, we'll discuss Cepheus, Draco, and Ursa Major. These objects can all be spotted with a medium to large-sized telescope under dark skies.



From left to right: Ursa Major, Draco, and Cepheus. Credit: Stellarium Web.

- **Herschel's Garnet Star:** Mu Cephei is a deep-red hypergiant known as The Garnet Star, or Erakis. While the star is not part of the constellation pattern, it sits within the constellation boundary of Cepheus, and is more than 1,000 times the size of our Sun. Like its neighbor Delta Cephei, this star is variable, but is not a reliable Cepheid variable. Rather, its brightness can vary anywhere between 3.4 to 5.1 in visible magnitude, over the course of 2-12 years.
- **The Cat's Eye Nebula:** Labeled a planetary nebula, there are no planets to be found at the center of this object. Observations taken with NASA's Chandra X-ray Observatory and Hubble Space Telescopes give astronomers a better understanding of this complex, potential binary star, and how its core ejected

enough mass to produce the rings of dust. When searching for this object, look towards the ‘belly’ of Draco with a medium-sized telescope.



This composite of data from NASA's Chandra X-ray Observatory and Hubble Space Telescope gives astronomers a new look for NGC 6543, better known as the Cat's Eye nebula. This planetary nebula represents a phase of stellar evolution that our sun may well experience several billion years from now.

The Cigar Galaxy.

- **Bode’s Galaxy and the Cigar Galaxy:** Using the arrow on the star map, look diagonal from the star Dubhe in Ursa Major. There you will find Bode’s Galaxy (Messier 81) and the Cigar Galaxy (Messier 82). Sometimes referred to as Bode’s Nebula, these two galaxies can be spotted with a small to medium-sized telescope. Bode’s Galaxy is a classic spiral shape, similar to our own Milky Way galaxy and our neighbor, Andromeda. The Cigar Galaxy, however, is known as a starburst galaxy type, known to have a high star formation rate and incredible shapes. This image composite from 2006 combines the power of three great observatories: the Hubble Space Telescope imaged hydrogen in orange, and visible light in yellow green; Chandra X-Ray Observatory portrayed X-ray in blue; Spitzer Space Telescope captured infrared light in red.

Bode’s Galaxy

Possible atmosphere surrounding rocky exoplanet

SCIENCENEWS, MAY 8, 2024

Researchers using NASA's James Webb Space Telescope may have detected atmospheric gases surrounding 55 Cancri e, a hot rocky exoplanet 41 light-years from Earth. This is the best evidence to date for the existence of any rocky planet atmosphere outside our solar system.

Renyu Hu from NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, is lead author on a paper published today in *Nature*. "Webb is pushing the frontiers of exoplanet characterization to rocky planets," Hu said. "It is truly enabling a new type of science.”

Super-Hot Super-Earth 55 Cancri e

55 Cancri e (image below, details/download), also known as Janssen, is one of five known planets orbiting the Sun-like star 55 Cancri, in the constellation Cancer. With a diameter nearly twice that of Earth and density slightly greater, the planet is classified as a super-Earth: larger than Earth, smaller than Neptune, and likely similar in composition to the rocky planets in our solar system.

To describe 55 Cancri e as "rocky," however, could leave the wrong impression. The planet orbits so close to its star (about 1.4 million miles, or one-twenty-fifth the distance between Mercury and the Sun) that its surface is likely to be molten -- a bubbling ocean of magma. With such a tight orbit, the planet is also likely to be tidally locked, with a dayside that faces the star at all times and a nightside in perpetual darkness.

In spite of numerous observations since it was discovered to transit in 2011, the question of whether or not 55 Cancri e has an atmosphere -- or even *could* have one given its high temperature and the continuous onslaught of stellar radiation and wind from its star -- has gone unanswered.

"I've worked on this planet for more than a decade," said Diana Dragomir, an exoplanet researcher at the University of New Mexico and co-author on the study. "It's been really frustrating that none of the observations we've been getting have robustly solved these mysteries. I am thrilled that we're finally getting some answers!"

Unlike the atmospheres of gas giant planets, which are relatively easy to spot (the first was detected by NASA's Hubble Space Telescope more than two decades ago), thinner and denser atmospheres surrounding rocky planets have remained elusive.

Previous studies of 55 Cancri e using data from NASA's now-retired Spitzer Space Telescope suggested the presence of a substantial atmosphere rich in volatiles (molecules that occur in gas form on Earth) like oxygen, nitrogen, and carbon dioxide. But researchers could not rule out another possibility: that the planet is bare, save for a tenuous shroud of vaporized rock, rich in elements like silicon, iron, aluminum, and calcium. "The planet is so hot that some of the molten rock should evaporate," explained Hu.

Measuring Subtle Variations in Infrared Colors

To distinguish between the two possibilities, the team used Webb's NIRCam (Near-Infrared Camera) and MIRI (Mid-Infrared Instrument) to measure 4- to 12-micron infrared light coming from the planet.

Although Webb cannot capture a direct image of 55 Cancri e, it can measure subtle changes in light from the system as the planet orbits the star.

By subtracting the brightness during the secondary eclipse (image below, details/download), when the planet is behind the star (starlight only), from the brightness when the planet is right beside the star (light from the star and planet combined), the team was able to calculate the amount of various wavelengths of infrared light coming from the dayside of the planet.

This method, known as secondary eclipse spectroscopy, is similar to that used by other research teams to search for atmospheres on other rocky exoplanets, like TRAPPIST-1 b.

Cooler than Expected

The first indication that 55 Cancri e could have a substantial atmosphere came from temperature measurements based on its thermal emission (image below, details/download), or heat energy given off in the form of infrared light. If the planet is covered in dark molten rock with a thin veil of vaporized rock or no atmosphere at all, the dayside should be around 4,000 degrees Fahrenheit (~2,200 degrees Celsius).

"Instead, the MIRI data showed a relatively low temperature of about 2,800 degrees Fahrenheit [~1540 degrees Celsius]," said Hu. "This is a very strong indication that energy is being distributed from the dayside to the nightside, most likely by a volatile-rich atmosphere." While currents of lava can carry some heat around to the nightside, they cannot move it efficiently enough to explain the cooling effect.

When the team looked at the NIRCam data, they saw patterns consistent with a volatile-rich atmosphere. "We see evidence of a dip in the spectrum between 4 and 5 microns -- less of this light is reaching the telescope," explained co-author Aaron Bello-Arufe, also from NASA JPL. "This suggests the presence of an atmosphere containing carbon monoxide or carbon dioxide, which absorb these wavelengths of light." A planet with no atmosphere or an atmosphere consisting only of vaporized rock would not have this specific spectral feature.

"We've spent the last ten years modelling different scenarios, trying to imagine what this world might look like," said co-author Yamila Miguel from the Leiden Observatory and the Netherlands Institute for Space Research (SRON). "Finally getting some confirmation of our work is priceless!"

Bubbling Magma Ocean

The team thinks that the gases blanketing 55 Cancri e would be bubbling out from the interior, rather than being present ever since the planet formed. "The primary atmosphere would be long gone because of the high temperature and intense radiation from the star," said Bello-Arufe. "This would be a secondary atmosphere that is continuously replenished by the magma ocean. Magma is not just crystals and liquid rock; there's a lot of dissolved gas in it, too."

While 55 Cancri e is far too hot to be habitable, researchers think it could provide a unique window for studying interactions between atmospheres, surfaces, and interiors of rocky planets, and perhaps provide insights into the early conditions of Earth, Venus, and Mars, which are thought to have been covered in magma oceans far in the past. "Ultimately, we want to understand what conditions make it possible for a rocky planet to sustain a gas-rich atmosphere: a key ingredient for a habitable planet," said Hu.

This research was conducted as part of Webb's General Observers (GO) Program 1952. Analysis of additional secondary eclipse observations of 55 Cancri e are currently in progress. ☀

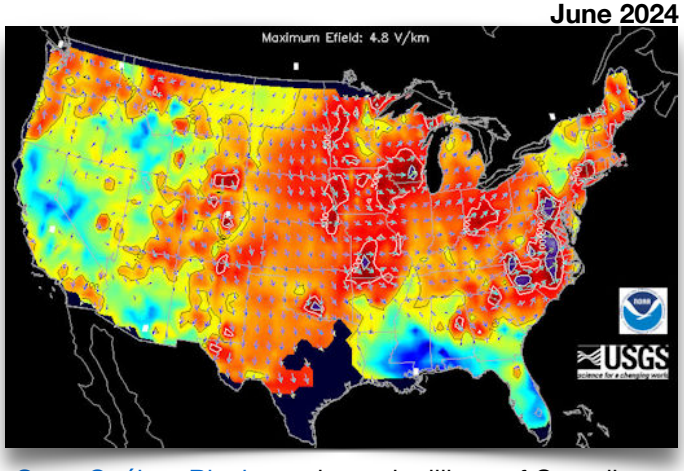
ROCKS AND SOIL ELECTRIFIED BY THE SUPERSTORM

SPACEWEATHER.COM, MAY 24, 2024

Across the USA on May 10th and 11th, sky watchers marveled at bright displays of aurora borealis during the biggest geomagnetic storm in decades. Little did they know, something was also happening underfoot.

Strong electrical currents were surging through rocks and soil. The biggest voltages along the US eastern seaboard and in the Midwest were as much as 10,000 times normal. A map from NOAA and the US Geological Survey shows some of the 'hot spots' during the early hours of May 11th.

Back in March 1989, voltages only a little stronger than the ones shown above brought down the entire Hydro-Québec power system. The resulting



Great Québec Blackout plunged millions of Canadians into darkness.

This time, however, power grids stayed up. "We haven't heard of any serious problems so far," reports Christopher Balch of NOAA's Space Weather Prediction Center.

Balch leads an effort at NOAA to model geoelectric fields during solar storms. The map, above, is a snapshot from a real-time display that takes into account the 3D conductivity of the Earth and ongoing geomagnetic activity. A computer at the Space Weather Prediction Center crunches the data to produce minute-by-minute estimates of electricity in the ground.

"I started working on this in 2011 after a NOAA Space Weather Workshop where representatives from the power industry asked for a geoelectric field model," recalls Balch. "It's a collaboration between NOAA, the US Geological Survey and others; we now have a version that covers much of Canada and the United States"

When researchers talk about geoelectric fields they use units of volts per km (V/km). Earth's crust naturally contains quiet-time fields measuring as little as 0.01 V/km. During geomagnetic storms, these values skyrocket.

"On May 10-11, geoelectric amplitudes exceeded 10 V/km in Virginia and 9 V/km in the upper Midwest," says Jeffrey Love, a key member of the collaboration at the USGS. "These are very high. For comparison, we estimate that geoelectric amplitudes reached almost 22 V/km in Virginia during the March 1989 storm."

This means the May 2024 storm was, electrically speaking, about half as intense as the storm that blacked out Québec 35 years ago. That's too close for comfort. "Although power companies have taken measures to improve the resilience of their systems, no one would welcome another storm as intense as that of March 1989," says Love. ☀

The Backyard Observer, June 2024

By Rick Heschmeyer

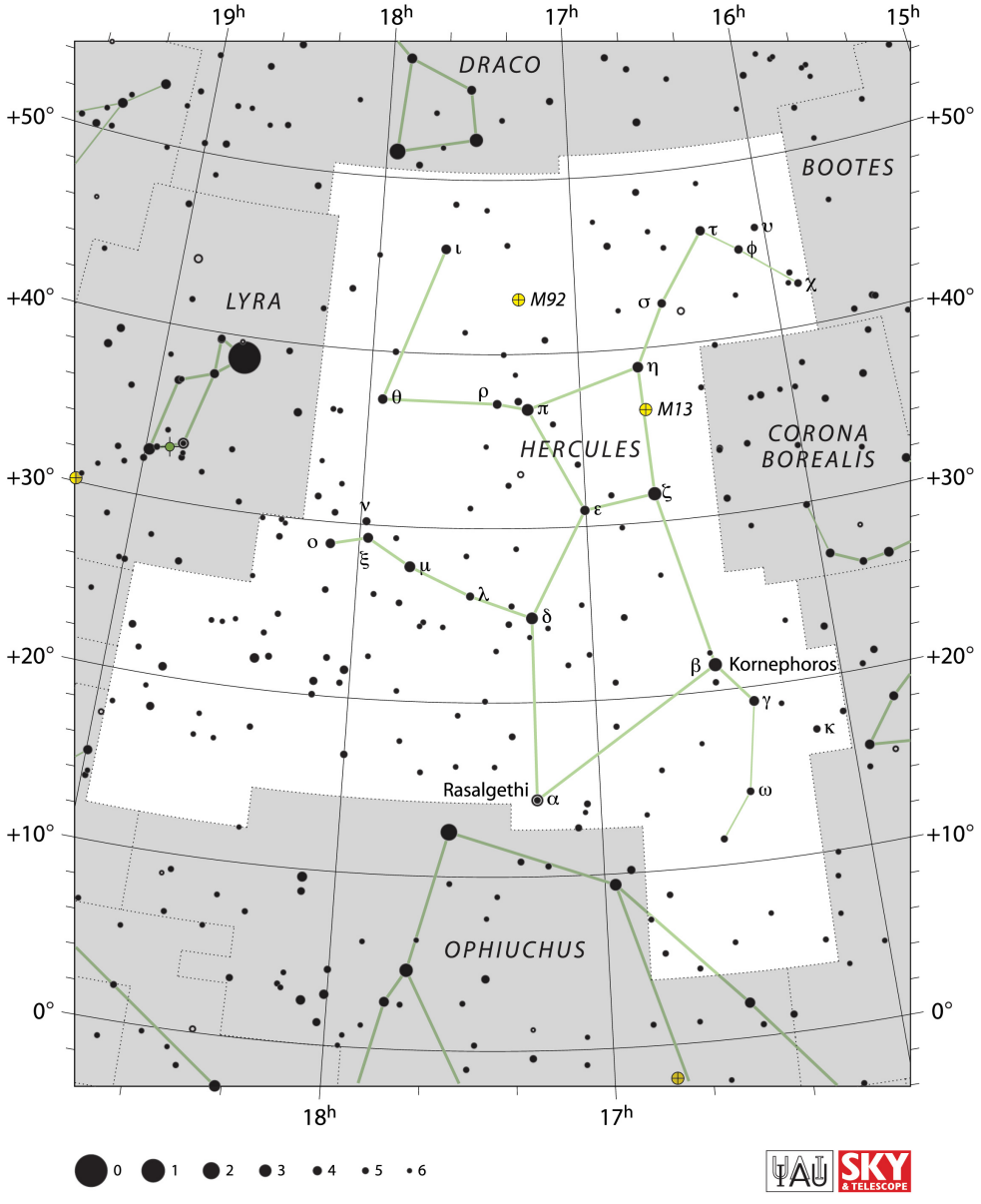
HERCULES

One of the finest objects in the northern night skies can be found in this month's feature constellation, Hercules, the Hunter. To locate the constellation, you must find the stars Pi, Eta, Zeta, and Epsilon Herculis. These four stars form a distinct asterism called the "Keystone", which makes up the torso of the Hunter, with his arms and legs extended from its four corners. In mythology, Hercules was the son of Zeus and the mortal Alcmene (who was the grandmother of the hero Perseus). A half-god with superhuman strength, Hercules spent his days protecting Olympus from various monsters and villains, as noted in his Twelve Labors.

Our first tour stop in Hercules is the brightest star in the constellation, Alpha Herculis, also known as Ras Algethi. This is a beautiful double star whose components are colored red-orange and blue-green.

Delta Herculis is another double star, but this one is an optical double, meaning the two stars are not physical bound by gravity, but simply lie along the same line of sight from Earth. The two stars colors have been described in various ways. I have read descriptions of one of the stars color ranging from ashy-white to blue-green to purple, while the second component has been described as ranging from yellow to green. What colors do you see?

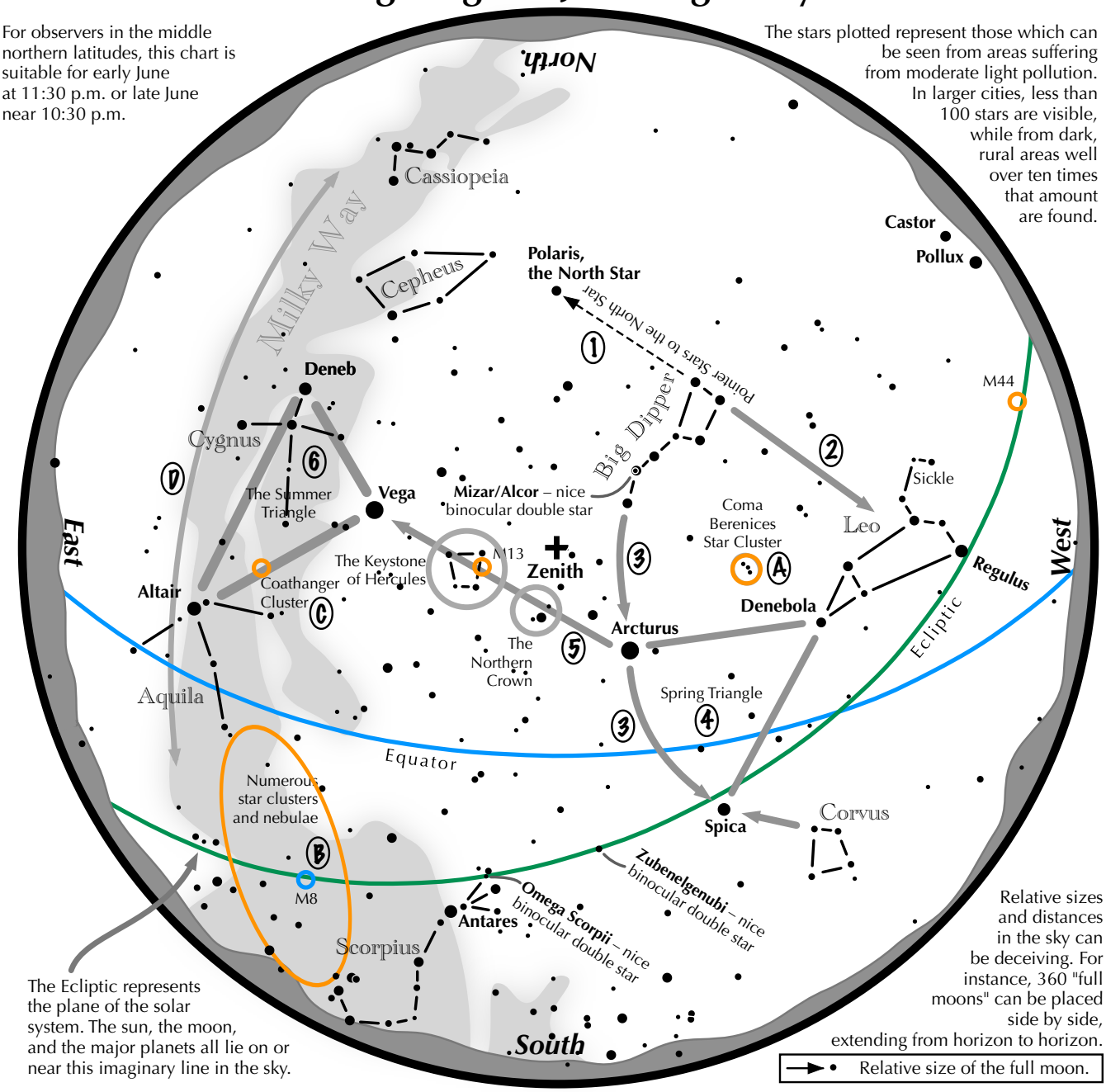
Let's return for a moment to the Keystone asterism. Located about one-third of the way from Eta to Zeta Herculis lies a small patch of fuzzy light, visible to the unaided eye from a dark location. This patch is actually a globular cluster known as Messier 13, the Great Globular Cluster in Hercules. Easily visible in binoculars and small telescopes, this cluster contains between 500,000 to 1,000,000 stars! Medium-sized telescopes will start to resolve some of the stars in the outer regions of the cluster. Globular clusters contain some of the oldest stars in our galaxy and are located not in the spiral arms of the galaxy like open clusters, but in a halo around our galaxy centered o the galactic core. Discovered in 1714 by Edmond Halley, of comet fame, Messier 13 in not only the brightest globular in the northern sky, but also one of the closest at a mere 21,000 light years away.



Navigating the June Night Sky

For observers in the middle northern latitudes, this chart is suitable for early June at 11:30 p.m. or late June near 10:30 p.m.

The stars plotted represent those which can be seen from areas suffering from moderate light pollution. In larger cities, less than 100 stars are visible, while from dark, rural areas well over ten times that amount are found.



The Ecliptic represents the plane of the solar system. The sun, the moon, and the major planets all lie on or near this imaginary line in the sky.

Relative sizes and distances in the sky can be deceiving. For instance, 360 "full moons" can be placed side by side, extending from horizon to horizon.

Relative size of the full moon.

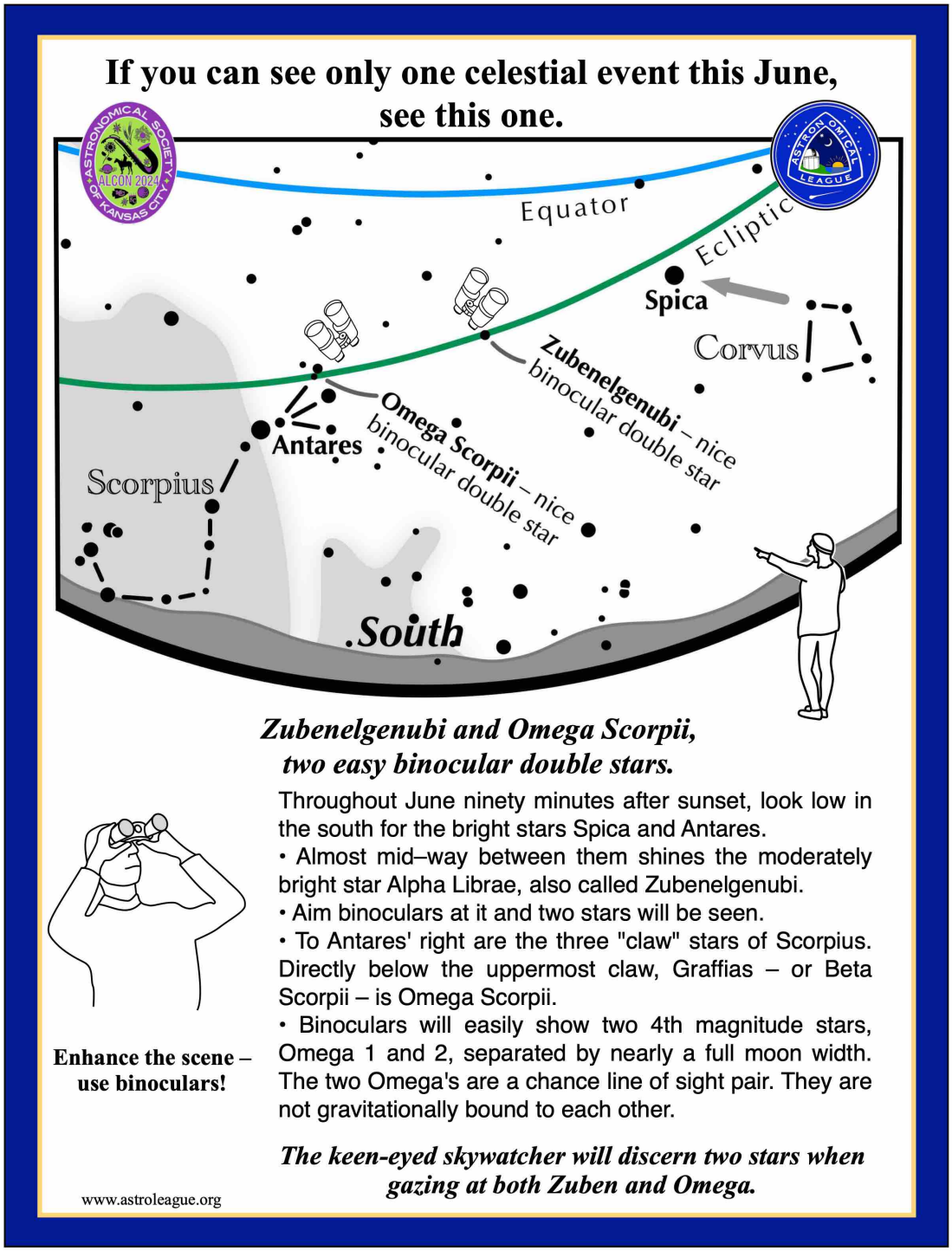
Navigating the June night sky: Simply start with what you know or with what you can easily find.

1. Extend a line north from the two stars at the tip of the Big Dipper's bowl. It passes by Polaris, the North Star.
2. Draw another line in the opposite direction. It strikes the constellation Leo high in the west.
3. Follow the arc of the Dipper's handle. It first intersects Arcturus, the brightest star in the June evening sky, then Spica.
4. Arcturus, Spica, and Denebola form the Spring Triangle, a large equilateral triangle.
5. To the northeast of Arcturus shines another star of the same brightness, Vega. Draw a line from Arcturus to Vega. It first meets "The Northern Crown," then the "Keystone of Hercules." A dark sky is needed to see these two dim stellar configurations.
6. High in the east are the three bright stars of the Summer Triangle: Vega, Altair, and Deneb.

Binocular Highlights

A: Between Denebola and the tip of the Big Dipper's handle, lie the stars of the Coma Berenices Star Cluster.
B: Between the bright stars of Antares and Altair, hides an area containing many star clusters and nebulae.
C: 40% of the way between Altair and Vega, twinkles the "Coathanger," a group of stars outlining a coathanger.
D. Sweep along the Milky Way for an astounding number of faint glows and dark bays.

Astronomical League *www.astroleague.org/outreach; duplication is allowed and encouraged for all free distribution.*



About Astronomy Associates

The club is open to all people interested in sharing their love for astronomy. Monthly meetings are typically on the last Sunday of each month and often feature guest speakers, presentations by club members, and a chance to exchange amateur astronomy tips. These meetings and the public observing sessions that follow are scheduled at the Baker Wetlands Discovery Center, south of Lawrence. All events and meetings are free and open to the public. Periodic star parties are scheduled as well.

Because of the flexibility of the schedule due to holidays and alternate events, it is always best to check the Web site for the exact Sundays when events are scheduled.

Copies of the Celestial Mechanic can also be found on the web at newsletter.
Annual Dues for the club are: $12 for regular members; $6 for students Membership forms can be accessed at the club website form.