Welcome to our relaunching of Sky’s Up — an online magazine designed to inspire readers to look up at the sky.

In this issue, we look at the closest and easiest object to observe in the evening sky — the Moon.

It is the second thing I ever saw in the night sky (the first was a meteor), and the object of my first serious astronomy project. Just before school began in the fall of 1964, I spent an evening at the Observatory of the Royal Astronomical Society of Canada’s Montreal Centre. With a friend, I met David Zuckon, a slightly older member about to embark on his final year at college.

“How would you like to come to my place and observe with a 3.5-inch reflector?” I asked. David answered with another question, “How would you boys like to come to my place and observe with an 8-inch reflector?”

It was obvious where we’d go. Once we got there, he deftly moved the big scope around to see Saturn, its rings, and its giant moon Titan — the only moon in the solar system known to have an atmosphere.

A few nights later David asked if I’d like to return for a second session. As we were observing, he mentioned that soon he would be leaving to complete his college education.

“I am looking for someone who could put this telescope to good use for the next two semesters, until I return in late spring.”

We talked about planetary work, and about double stars. I told him that during the summer I had completed the lunar training programme having spotted and drawn the 326 lunar features (300 craters and 26 mountain ranges and other features) on the Sky & Telescope lunar map. It is a project I had been working on for four years.

“You’ve done that?” David asked. “You’ve finished the lunar training programme?”

“Yes,” I repeated.

He paused for a few seconds and then said “Then you’ve just borrowed yourself a telescope!”

We moved the 8-inch to 818 Upper Belmont that very night, and I continued observing with it until dawn. Also that night I named the telescope Pegasus after a NASA project that launched three heavy satellites into orbit around Saturn (these were earlier versions of the Saturn V that eventually sent astronauts to the Moon).

The Moon pays no attention to light pollution. It is gorgeous without even using binoculars, and through a telescope, any telescope, it is spectacular quite beyond description.

Not only does the Moon show beauty, but also it teaches us something about the night sky for it does not stay in the same spot. Because it revolves about the Earth, it moves about its own diameter every hour and circles the entire sky in less than a month.

It ranges in brightness from a thin sliver of a crescent almost impossible to see in bright twilight to a brilliant glowing ball that utterly dominates the night sky. And there’s more: As the Moon orbits the Earth, it moves from a place relatively far from Earth to a place much closer. When it is closest, it is at perigee, and if it is near full phase at that time we sometimes call that a supermoon. When it is farthest from Earth, we say it is at apogee.

The Moon has given me countless nights of joy. In fact my very first officially logged observing session — Session number one — involved a view of the Moon partially eclipsing the Sun on October 2, 1959. I was 11 years old, and my Moon drove my brother Gerry and me to the Lookout atop Westmount Mountain to catch a glimpse of the eclipse through passing clouds. Including this one, I have now seen 87 eclipses of the Moon or the Sun. Twelve of these events were total eclipses of the Sun.

The most recent eclipse was the total eclipse of the Moon that took place the morning of April 14. Even though the total phase of this eclipse was a record short five minutes, the great thing about this type of eclipse is that it can be seen over the full half of the Earth that happened to be in darkness at the time. A total eclipse of the Sun, on the other hand, takes place only when the tiny shadow of the Moon strikes a particular band across Earth, a band that may be less than a hundred miles wide.

In this issue there are other articles about the Moon, and how to enjoy looking at it. May you spend many, many nights under the stars, and even more enjoying the lovely Moon.

Over decades of observing, David Levy has discovered or co-discovered a total of 23 comets. His prolific record includes the joint discovery of Shoemaker-Levy 9, which quickly went on to dramatically crash into Jupiter in 1994, and the individual discoveries of two periodic comets — P/1991 L3 and P/2006T1 — through his backyard telescope. In 2010, Levy became the first person to have discovered comets in three ways - visually, photographically and electronically. Beyond his observation achievements, Levy has authored, edited or contributed to more than 30 books and has periodically provided articles for publications like Sky & Telescope and Parade Magazine.
Meteor showers galore!

Our bustling solar system is littered with rocky particles of space debris known as meteoroids. Although most are unimpressive in size, these pebble-sized pieces of cosmic clutter can still put on quite a show for earthbound observers. When a meteoroid plunges into the Earth’s atmosphere, it is traveling at phenomenal speeds. The drag caused by the air it encounters, heats both the meteoroid and the air molecules. This intense interaction ionizes surrounding atmospheric gases to create the fleeting glowing trails of light we know as meteors. Although the potential is there on any given night, witnessing a sporadic meteor is not a frequent experience for most. Luckily, some cyclical celestial objects like comets and asteroids leave behind streams of debris that the Earth will cross paths with on a regular basis. When this happens, meteor activity increases noticeably and, sometimes, dramatically. Known as meteor showers, these predictable events are a great time to try and catch multiple shooting stars. These include:

- **Oct. 8-9 - Draconid Meteor Shower**

  Although it usually does not result in an impressive amount of meteors per hour, the Draconid event is a notable rarity among meteor showers because these meteors are best seen in the early evening instead of in the more common post-midnight hours. The radiant point for this meteor shower, which is caused by debris from Comet 21P/Giacobini-Zinner, is in the head of the Draco the Dragon constellation. Set to peak around October 8th, the shower usually only produces a few meteors per hour, but it is unpredictable and has produced hundreds per hour in some years.

- **Oct. 21-22 - Orionid Meteor Shower**

  Generated when the Earth crosses paths with the dust left behind by Halley’s Comet, the Orionids radiate from the constellation Orion and generally last for about a week in late-October. Observers can typically see 10-25 meteors per hour during the shower’s peak activity time, which will begin late evening on October 21st and last into the predawn hours of October 22nd. Although the Orionids move fast, they have been known to leave a glowing gas trail that lasts for a few stunning seconds.

- **Nov. 17-18 – Leonid Meteor Shower**

  Set to peak in the predawn hours of November 18th, the always-anticipated Leonid meteor shower is an annual November phenomenon caused by the Earth’s passage through debris left behind by comet Tempel-Tuttle. Although it has a history of producing stunning meteor storms every few decades, the shower usually generates a steady 15 to 20 meteors per hour, which is this year’s expected rate. The Leonids radiate from the Leo constellation.

- **Dec. 13-14 – Geminids Meteor Shower**

  The Geminid meteor shower is traditionally one of the year’s most prolific — producing more than 100 bright meteors per hour during its peak, which will be between midnight and dawn on December 14th this year. It is not just the height of activity that makes the Geminids notable. In fact, their origins make it truly unusual because instead of being generated by the debris left behind by a comet, they are caused by the asteroid 3200 Phaethon, which orbits the sun every 1.4 years. This year the show should be particularly impressive because the thin crescent Moon will provide little if any interference.

**viewing tips**

- When selecting an observing spot, try to find a dark open sky away from light pollution.
- Remember the best viewing hours are usually between midnight and dawn.
- Look at the whole sky for meteors, and do not confine yourself to the radiant point.
- Bring a blanket to stretch out on or a reclining chair for comfortable viewing.
- Bring extra layers (jackets, blankets, etc.) if you plan to stay out for a long time.
- Once you are settled at your observing site, give your eyes time to adjust to the darkness.
- Be patient!

This time-lapse photo captures the progression of the last total lunar eclipse, which took place on October 8, 2014.

**Lunar tetrad wraps up with September eclipse**

Observers in the Americas — especially South America — will be perfectly positioned to witness the Moon take on a red hue as a total lunar eclipse unfolds on September 27th. The last total lunar eclipse, which occurred on April 4, lasted just under 5 minutes making it the shortest total lunar eclipse of the century. This time, the total phase of the eclipse will last a leisurely 72 minutes.

A total lunar eclipse occurs when a nearly perfect alignment of the Sun, Earth and Moon causes the Full Moon to be shrouded by Earth’s deepest shadow. During the event, the same phenomenon that gives our sunsets their beautiful, colorful glow will cast the Moon in some shade of burnt reddish-orange. How red the Moon will actually appear depends on Earth’s atmospheric conditions, such as dust levels and humidity, that affect the way sunlight is filtered and refracted to light the lunar surface.

The eclipse’s total phase begins at 2:11 UT on September 28th (10:11 p.m. EDT on September 27th). The partial phase, which begins at 1:07 UT on September 28th (9:07 p.m. EDT on September 27th), will last a generous three hours and 20 minutes and give many an opportunity to watch the Earth’s shadow’s colorful march across the lunar surface. In addition to putting on a spectacular show in the Americas, the September 27/28 eclipse will be visible in part or in full to observers in Europe, Africa and parts of Asia. It is the last in a series of four consecutive lunar eclipses that are all total eclipses. The series, which is known as a lunar tetrad, began in 2014. The next lunar tetrad will begin in 2032.
Top honorees speak at ALCon

Theodora Mautz:

“The research question I examined was: ‘How do the galactocentric distances of Milky Way globular clusters affect their rotational velocities about the galactic center?’

I extracted data on globular clusters’ rotational velocities and distances from the center of the Milky Way, and generated a rotation curve similar to astronomer Vera Rubin’s rotation curve for Milky Way disk stars. My hypothesis was that there would be no relationship between the two variables, as Rubin found in the 1970s with stars in the Milky Way’s disk, because I believed there to be pervasive dark matter content in the halo of our galaxy.

Sure enough, after running two statistical analyses on the data, I found there to be no relationship! Granted, there were many limitations with my data and so its conclusions are tentative. Still, my results support the theory that there are large quantities of dark matter throughout the Milky Way halo, which is a really fascinating idea!”

Sydney Marler:

“My research explores the most powerful explosions in the universe; gamma ray bursts. In one second, a gamma ray burst emits more energy than some stars will in their entire lifetimes. A long standing mystery in the field has been the issue of ‘dark gamma ray bursts,’ which are gamma ray bursts that don’t emit an optical afterglow. These explosions, which make up about a fourth of gamma rays bursts, are essentially ‘invisible.’

I used x-ray spectroscopy data from the NASA Swift Space Telescope to look for some kind of pattern in these dark gamma ray bursts that might tell us more about where these explosions come from and what causes their ‘invisibility.’ I ended up finding huge amounts of magnesium in the x-ray spectra of dark gamma ray bursts. This was a really exciting moment for me because finding magnesium led somewhere that gamma ray burst research seldom goes — into the hearts of galaxies and massive stars.

Not only does this mean huge implications for where we might search for life, but also for understanding what goes on inside a star to produce a huge explosion. Next to nothing is known about how a gamma ray burst is produced and my research could give a major clue as to what causes the most powerful explosions in the universe.”

When Marler describes her experience at ALCon, it conjures up the same sense of inspiration that she found in the eyepiece of that telescope as a young girl.

“If I had to describe ALCon in one word it would be community. While there were many times during my research that I doubted myself, everyone at ALCon was bursting with so much optimism about my future endeavors and were so supportive,” she said.

Sydney Marler

Sydney Marler

Sitting in a room where every single person feels the same sense of wonder and curiosity about the universe is something I will never forget,” Marler said.

For more information, click here.
what’s up in the sky

Oct. 11 – Uranus at Opposition

On October 11th, our solar system’s third largest planet, Uranus, will be in a prime viewing position almost all night, peaking at midnight local time. Even though Uranus, which will be located in the Pisces constellation, will appear at its brightest and largest in the night sky during this event, naked eye observations will reveal little more than a star-like point. To really see this remote planet, expect a palespikes mirror, you will need a moderate-powered telescope, and a large scope may reveal some of the planet’s many moons.

Oct. 16 – Mercury at Greatest Elongation

On October 16th, Mercury will be a bright presence in the predawn sky as it moves into a prime position for early morning viewing. Because it is always so close to the Sun, Mercury is usually lost in its glare. But on this day it will be at its furthest point to the west of the Sun, which means it will rise more than an hour before the Sun in some places. A clear sunrise horizon is essential for viewing Mercury. While this often elusive planet will be visible to the naked eye, a pair of binoculars or a small telescope could provide additional details.

Oct. 28 – Venus, Mars & Jupiter

As the third brightest object in the sky, Venus is consistently an inspiring celestial target for both casual and avid sky watchers. But on October 28th, the brilliant planet will have to share the celestial spotlight with Jupiter and Mars as the three cozy up in a fairly rare “planetary trio.” During the event, the three planets will visually lie within a few degrees of one another in the Leo Constellation. After perusing the planets, observers can take in Leo’s brightest star - the well-known Regulus — that will shine nearby. Boosting an apparent visual magnitude of 1.35, this blue-white beauty anchors the sicle-shaped asterism that defines the head of the Lion and is said to represent the beast’s heart.

November – Andromeda Galaxy

Autumn’s dark skies make a perfect stage for viewing the beauty of the bright Andromeda Galaxy, which sits high in the sky from dusk to dawn. Located at about 2.5 million light years away from Earth, the Andromeda Galaxy is the closest major galaxy to our own Milky Way. Although it is the most distant object the naked eye can see, binoculars can be a handy aid for locating the galaxy, and a telescope will reveal its spiral details and its much smaller companion galaxies known as M32 and M110. To locate the galaxy, find the Great Square and look for two streams of stars that shut off of it into the Andromeda constellation. An imaginary line drawn up from the middle star of the bottom stream to the middle star in the upper stream, will point to Andromeda.

Dec. 7 – Venus and the Moon

The night sky’s two brightest jewels will snuggle up in the predawn sky on December 7th. During the lovely pairing, Venus and the Moon will pass within .38 degrees of one another. Observers in northwestern North America will actually be able to witness the Moon occult or mask Venus during the event.

Dec. 21 – Ursids Meteor Shower Peaks

Although the nearly Full Moon will dampen the show, meteor shower enthusiasts might still want to watch for the peak of the Ursids meteor shower, which is expected to occur in the wee hours of December 21st. Long associated with debris from Comet 8P/Tuttle, the Ursids radiate from the Urca Minor constellation and generate a maximum of about 10 meteors per hour during their peak time.

Search for ET stronger than ever

It’s arguably the hottest research topic in astronomy today: the hunt for planets around other stars. The tally of positively identified worlds, a number that is increasing at an accelerating pace, has surpassed a thousand. We now know something that no one knew twenty years ago: planets are as common as coffee cups. But most planets – at least judging by our own solar system – are awful places, either barren balls of rock or giant gassy globes. Interesting to photograph, but not hospitable to life. So astronomers are still dealing with a big puzzle: How many planets are somewhat like Earth, with oceans and atmospheres? A recent analysis suggests that one in five stars has such a biology-friendly world. If so, then there are tens of billions of “Earth’s cousins” in our own Milky Way Galaxy.

That’s a bumper crop of first rate real estate, and it encourages us to think the cosmos could be bursting with life. It doesn’t take much imagination to expect that some of that life will be intelligent, in the way that we are. These developments have given new incentive to the experiments known as SETI – the Search for Extraterrestrial Intelligence. With so many places where other beings could exist, it would be crazy not to look for them.

But how do we do that? While there are many schemes for discovering aliens, the most common method is to point large antennas at the sky, hoping to eavesdrop on ET’s broadcasts. Perhaps some other societies are sending a signal our way. Perhaps we could just be lucky and pick up the radio leakage coming from their world, much like the television and radio signals that fly off our own planet.

Today, the SETI Institute, in northern California, is using a small group of antennas known as the Allen Telescope Array to search for signals arriving from nearby star systems. So far, we haven’t tuned in a broadcast from anyone (other than annoying interference from transmitters on Earth). But then again, we’ve only examined several thousand places on the sky in great detail. So – given that our galaxy has a few hundred billion star systems – it’s hardly surprising that we haven’t yet uncovered ET.

But the equipment used to make the search gets faster as computers improve. In the next two decades, we might be able to listen in the directions of a million star systems or more. That’s a big improvement, and frankly I think it’s quite possible that we could soon pick up a faint radio signal that would tell us someone is out there. Think about it: Ever since the time of the cave men, humans have looked up at the night sky and wondered if anyone was up there. Yours might be the first generation to discover that the answer is yes.

Dr. Seth Shostak is the Senior Astronomer and Director of the Center for SETI Research at the SETI Institute.
It’s a steady presence in all of our lives, but few people take the time to truly get to know Earth’s closest neighbor.

In this recurring feature, accomplished astronomer and astrophotographer Dr. Howard Eskildsen will take readers on a quadrant by quadrant journey across the luminous face of the Full Moon.

Through his images and words, Eskildsen will explore the legions of geological formations that give the Moon its distinct personality. His in-depth information will give context to the features that pop to life when one views our oft romanticized satellite through a telescope or other optical aid.

Over the next few pages, the impacts of volcanoes, meteors and other forces will be revealed in detail.

From its contribution to our tides to the artistic inspiration it provides, the Moon’s influence on Earth is profound, and it deserves a deeper look.

“The Moon is a wonderful friend and companion to the Earth and its residents. Hardly a day goes by that someone does not hear me say, ‘Oh! Look at the Moon.’ It is like Earth’s little brother, and a rocky soul mate to all who dwell here.”

— Howard Eskildsen
Copernicus to Lansberg

Copernicus stands out as an eye-catching crater on the upper right corner of the quadrant. The 96 km diameter crater typifies the structure of large craters on the moon. A prominent group of peaks rises near the center of the crater, surrounded by a flat inner floor. The inner rim rises from the floor in a series of steps or terraces to the roughly circular outer crater rim. Outside the rim, rough rubble extends in an ever thinning ring that extends nearly a full crater diameter beyond the outer ring. This material, known as ejecta, was violently ejected during the formation of the crater by an explosive impact of an asteroid or comet. Intermittent fingers of ejecta extend even farther than the continuous apron surrounding the crater. Additionally, small irregular craters appear in the surrounding area that are secondary craters from blocks of material ejected during the crater formation.

Reinhold and Lansberg, 49 and 41 km diameters respectively, show similar structural features to Copernicus on a smaller scale, but appear softened in appearance as if there has been some weathering compared to Copernicus. They are older than Copernicus and have endured eons of erosion caused by strikes from small meteors, known as gardening. Both also endured a massive moonquake by the formation of Copernicus as well as scouring from material ejected from it.

The lower left half of the quadrant consists of a mostly smooth surface interrupted by scattered craters. Some of those craters appear fresh and deep, while others appear worn and shallow; indeed there is a nearly completely buried crater between Lansberg and Hortensius with only its outer rim rising above the plains. What could have buried and nearly completely filled the crater? The plains consist of a type of lava known as basalt and are known as mare (singular) or maria (plural), such as Mare Insularum on the image. It arose from swarms of fractures in the lunar surface and, layer by layer, laid down the smooth plains. Either before or during the emplacement of the basalt, the flooded crater formed by meteor impact, and then was filled inside and out by rising lava until only the uppermost portion of its outer rim remained. Tests run on the basalt recovered from the moon’s lava plains by the Apollo missions show that it was about as thin and runny as warm motor oil or pancake syrup, and flowed freely into flat layers.

Later, when that phase of volcanism had ended, some last gasps of volcanic activity left domes of lava that was much thicker when it erupted. The rounded domes the lava formed feature central pits or caldera. Several of these are visible on this image including the Hortensius Domes and Dome π near Milichius.

In this image it is possible to see several processes that have shaped the moon over the eons. There are craters caused by impacts with meteors, asteroids or comets. Erosion of the craters shows up as wear from impacts of small meteors, from shaking from large nearby impacts and by volcanic flows. Two different forms of volcanism are visible: the flat basalt plains and rounded volcanic domes with central caldera pits. Many other processes shape the surface of the moon and will be revealed as we continue to explore other quadrants.
At the top of the image the crater Eratosthenes appears like a smaller version of Copernicus. Though only 60 km in diameter, Eratosthenes is structured like Copernicus with central peaks, flat floor, terraced inner rim and a continuous ejecta apron outside the outer rim. However, it lacks rays and its features appear softer and more subdued than those of Copernicus. Why? Eratosthenes is older and has had more time for multiple meteor impacts to erode or garden its surface. Similarly its rays have vanished due to the erosive forces. It is estimated that it takes about a billion years to erase a crater’s rays, so Eratosthenes must be considerably older than Copernicus. By using Apollo 14 rock samples returned to Earth, scientists estimated the age of Copernicus to be 800 million years. Wow! No eyes existed on Earth to witness the cosmic crash that created it. Eratosthenes then is much, much older. It is estimated to be around 3.2 billion years old; only the most primitive forms of life inhabited Earth when it was formed.

The two earliest lunar geological time periods are named after these two craters. The Copernican period runs from current day to approximately 1.1 billion years ago and is defined by craters with bright rays. The Eratosthenian period runs from 1.1 billion to 3.22 billion years ago and is characterized by distinct craters without rays. Some volcanic activity occurred during this time. It was slowly ending but had not totally ceased during this period. Eratosthenes is bounded on three sides by flat mare plains of basaltic lava, including Sinus Aestuum. Could encroaching lavas have partly buried part of its ejecta and rays? A close look at higher resolution shows that its ejecta is in fact littered over the mare basalts, so the last layers of lava are older than Eratosthenes, though in general they appear very close in age. As noted above, those lavas and Eratosthenes are overlain by rays and secondary craters from Copernicus, confirming that Copernicus is younger than both features. In contrast, poor Stadius is obviously older than the lava flows which nearly obliterated it. Only portions of its outer rim still rise above the basalt.

Other volcanism is visible in the form of pyroclastics (fragmented rocks and ash from volcanic explosions) thought to have been the last gasps of volcanism in the region. The pyroclastics on this image appear to have been partly covered by rays from Copernicus, so are obviously older. Much later humans left an unintended mark (not visible in telescopes) in the region southwest of the pyroclastics. Surveyor 2 tumbled out of control during a course correction rocket misfire and crashed onto Mare Insularum. Two craters appear to the left and below the Surveyor 2 impact site. They are Gambart C (12.2 km) and Gambart B (11.5 km) and are classified as simple craters since they lack central peaks and have smooth inner rims. Simple craters are generally less than 15 km in diameter whereas craters over 20 km generally have characteristics like Eratosthenes and Copernicus and are known as complex craters.

Finally, other ruins of craters lie at the bottom of the image. Gambart appears as an irregular ring inundated by mare basalt. Mosting appears as the least worn crater on the lower image, but Sömmering and Schröter were hideously deformed long before they were covered by basalts. Why? The explanation will follow in subsequent quadrant descriptions.
This region features broad expanses of basaltic lava plains interrupted by craters large and small, fresh or ruined. Mountain peaks punctuate the landscape here and there, and rocky rubble litters the upper right margin of this image. All tell stories, like the pages of a book, of triumph and disaster on the moon. 

**Lansberg** at the top of the image is well preserved with all the features of a large crater distinct, except for the absence of rays radiating from its rim. Simple craters such as Euclides, Eppinger, Kuiper and Darney dot the landscape as well. Of the four mentioned, only Euclides shows any hints of rays suggesting that the others are more than a billion years old, since space weathering tends to eliminate rays within a billion years. This is partly due to “gardening” from meteoroids impacting and from the effects of solar wind changing iron oxides into tiny flecks of iron known as nanophase iron, which gives the undisturbed lunar surface its characteristic color. Other unlabeled craters also show some rays, revealing their “youthful” Copernican age.

Mountains also punctuate the surface as isolated peaks or as curious partial arcs, such as the Riphaeus Mountains. Look closely and you will find other curving ridges. They all hint at the primary cause of mountain building on the moon: crater-forming impacts. They were all at one time or another parts of crater rims, but were subsequently partially buried or eroded into their current forms. The burying is obviously from the lavas, also known as mare basalts that pave much of the visible surface in this image. But what could cause massive erosion and scarring such as seen at Fra Mauro, Bonpland and Parry?

The region labeled **Imbrium Ejecta** is similar to the rough rubble seen surrounding Copernicus in quadrant 37. It is material that was ejected at high velocity from a massive impact that formed a crater so large that it is known as an impact basin and is named Imbrium. Unlike smaller craters, impact basins have multiple concentric rims. Imbrium’s most prominent rim is 1,160 km in diameter and is located nearly 600 km north of Fra Mauro. When **Mare Imbrium** exploded onto the scene it wreaked devastation, and many craters were lucky to have survived, even in a ruined state. Note the left half of Fra Mauro, and the creased rims of Bonpland and Parry; they were scarred and filled by ejecta in a matter of minutes and then shaken into final shape by seismic waves that jolted through the moon away from the basin. Later mare lavas covered over some of the ejecta as well. Eons later, humans left their marks on the moon (though not visible through a telescope). Ranger 7 took detailed images as it streaked to an intentional crash landing in the area known in its honor as **Mare Cognitum** (the known sea). Later, Surveyor 3 made the first successful soft landing on the moon by an American space probe in 1967. Two and a half years later, Apollo 12 landed only a few hundred feet away from Surveyor in an area called Pete’s parking lot, in honor of mission commander Pete Conrad. The successful pinpoint landing confirmed that all lunar module’s energy “residuals” had finally been accounted for. Apollo 11 had landed nearly 4 miles from its intended target due to calculation errors of the residuals, and correction of these errors made it possible to pursue future lunar landings that required precise landing for the survival of the mission.
Why do we need a lunar base? How can a lunar base help us expand our space exploration options?

There are several reasons for having a lunar base. It can be used as a stepping stone for a future trip to Mars or asteroids. Another advantage is to have a base for more accurately studying the evolution of the Moon and for preparing for future colonization. There is considerable interest in finding ways of extracting water from the lunar polar regions for supplying future colonists. At the present time there is no NASA funding allocated for a lunar base, however other nations are actively considering this possibility.

How are the bricks made now, and how will the process be different in space? What energy source would be used?

Bricks made on Earth usually contain various components that help bind the brick material together. One option is to send up these binding components for making bricks in space, however, it will be very expensive to do that. There are several energy sources being evaluated for use on the Moon or Mars. We are evaluating the use of microwaves. Other researchers are evaluating focused solar energy.

On December 14, 1972, U.S. Astronaut Gene Cernan made the last boot print on the Moon as he stepped off the lunar soil to board the Apollo 17 Lunar Module. Although decades have passed since humanity left the Moon behind, interest in what our solemn companion can teach us has not diminished. In fact, the desire in the scientific community to revisit the Moon and venture beyond is very much alive.

A team at NASA’s Jet Propulsion Laboratory has put this “when we go” attitude into action by developing a method to create the building materials necessary for habitation of the Moon or Mars out of a readily available resource. Their solution is a microwave heating system that can completely melt lunar or Mars regolith (soil) into a substance that can be used to make bricks and even roads on site. In an effort to further support these future missions by addressing essential life support needs, the team is currently evaluating how this microwave heating process might be used to extract consumables like water from various regolith types.

In this installment of Sky’s Up’s “10 Questions” feature, JPL colleagues Dr. Martin Barmatz and David Steinfeld answer questions about the project.
How do you simulate building conditions on the Moon and/or Mars while working with the materials on Earth?

Usually initial studies are performed under Earth’s atmosphere. Later, the building techniques can be evaluated either in a vacuum (like on the Moon) or in a low pressure CO2 atmosphere (similar to that on Mars).

How would the bricks be assembled into an actual structure, and how would it be anchored to the surface? What seals the bricks together, and would the structure be airtight?

There are many approaches that are being investigated to address these questions. One approach we are looking at is to melt the regolith (lunar or Mars soil) using microwaves and then guide the melt into molds of various shapes or just let it drop to the ground to form a road. Many studies need to be conducted on these various approaches to determine the strength and stability of the resultant solid objects. For some applications like forming a road on the Moon, we will not need an airtight structure.

What would the final structure look like from the outside and from the inside?

The answer to that question will depend on the structure. For a road, you will only be seeing the top surface. For a building, there may be additional items adjacent to or attached to a brick wall. For example, we could visualize having an inflated balloon pressed against the walls of a brick constructed room to provide an atmosphere for astronauts.

What are the differences between the two types of soil? Will you have to contend with different soil composition depending on where you land? Is one easier to build with than the other?

The two soils do have different compositions. The lunar soils have been bombarded with micrometeorites because there is no atmosphere. This bombardment has caused the surface material to melt and re-solidify in a vacuum causing new compositions to form. Mars has an atmosphere and thus these compositions are not widely present. In our studies using microwaves, we have found it easier to heat and melt lunar regolith simulants than Mars simulants.

How are the soils different from Earth’s soil? Could you use the same system to build structures on Earth? Why or why not?

There is a significant difference between Earth’s soils and those of Mars and the Moon. The Mars and Moon soils are typically more granular than those of Earth and are very dry compared to the soils on Earth. Earth soils contain a higher concentration of organic compounds than those of Mars and the Moon. Studies have not been carried out to determine whether the techniques being considered for building structures on the Moon and Mars could be used on the Earth.

Besides being an abundant material, what other benefits are there to using lunar/Mars soil to build with?

The Mars soil has been shown to be a very good radiation shield that will provide protection for the astronauts.

What challenges would these structures face once they are built? Are there certain issues to consider like high winds, “earthquakes,” dust storms or solar radiation?

Space is a very hazardous environment. The structures would be constantly bombarded by radiation and micrometeorites. On Mars there are intense dust storms and dust devils as well as extreme day/night thermal variations. There does not appear to be much seismic activities on the Moon or Mars.

How would those living on the Moon and/or Mars deal with other needs like oxygen, water and food? Supply trips seem feasible to the Moon, but how about Mars?

NASA is currently addressing these issues in a program called the In Situ Resource Utilization program (ISRU). This program is specifically addressing these issues associated with future astronaut missions to the Moon or Mars. More information can be found [here](#). For initial trips to Mars, astronauts would take with them all the food and water they will need. On later trips, ISRU technology will be required. NASA is also experimenting on how to grow food in space with experiments aboard the International Space Station, so growing food on Mars is a possibility in the future.

Educators, if you would be interested in having your class participate in this recurring feature, please email your contact information to tricia@astronomyoutreach.com.
Understanding ‘The Moon in Our Sky’

The Moon is our closest celestial neighbor. It changes shape, sometimes it is in the evening sky, sometimes the morning sky, and sometimes it seems we cannot see it at all.

The purpose of “The Moon in Our Sky” activity is for students to individually observe the Moon over a period of time to better understand its phases, position in the sky and movement.

The number of times or period of observation is up to you – and the weather. At a minimum, students should track over a two week period, from new moon to full moon. That way they will get an opportunity to see how the shape of the moon – the phase – changes night to night. And they should also note how the position of the moon changes night-to-night, as the Moon orbits Earth.

There are a number of excellent phases of the moon videos on YouTube. You should select one that is appropriate for your students. One I wrote that might be a little too-high level for some age groups can be found here on YouTube.

The United States Naval Observatory has an excellent website that includes specific Sun and Moon data for one day. This will show you specifics like moonrise and moonset times as well as the Moon’s phase for your location for any date you choose.

Students can keep a log of their observations over a period of time. That way they can record the changes and compare these in their observing logs. It does not take a telescope, all they are recording is the shape of the Moon, and some other data that astronomers would include like the date and time.

Why is this type of observation important? First, it gets students thinking like a scientist: Making observations and recording data. Second, students can see the changes and a little better understand why we see these changes.

In addition to being a longtime STEM advocate, Dr. Mike Reynolds is a dean and professor of astronomy and physics at Florida State College and a recognized expert on meteoritics. He participated in NASA’s Teachers in Space Program and has served as executive director of the Chabot Space & Science Center.
This year, the festive and frightful Halloween holiday falls on a Saturday night, which means it will be a perfect time to stay up late to check out some of our night sky’s eeriest treats. The following is a list of some of the most popular spooky sights that dot the universe. Not all of these will be visible from all latitudes, but even if you cannot view them from the field, they are all worth checking out virtually.

**Witch Head Nebula**

Our haunting cosmic journey begins with a celestial witch hunt in Eridanus, which is visible from 32° North to 90° South. In this sprawling constellation, a faint but striking reflection nebula conjures up the image of an old crone. A great target for astrophotography, the appropriately named Witch Head Nebula has a mesmerizing blue glow that adds to its creepy quotient. The likely source of this illumination is the nearby blue supergiant Rigel, which is a main attraction in the Orion constellation.

**Cat’s Eye Nebula**

As complicated as the creature it is associated with, the Cat’s Eye Nebula is a bright planetary nebula that peers out of the night sky near the North Ecliptic Pole with an ominous blue-green glow. Although you can see it in modest telescopes, you will need to use high magnification to reveal any hints of its highly complex structure, which includes curving brown lines and radiating circles. Most will see it as a blue-green disc with a blazing central star. The nebula, which is located in the Draco constellation, is a great choice for a long-exposure photo.

**Ghost Nebula**

When it comes to nebulae, several are associated with ghosts, but there is one that is particularly unsettling. The Ghost Nebula looms in the Northern Hemisphere’s Cepheus constellation, which is in a prime observation position in November. This wispy reflection nebula manifests an intriguing brownish color around its edges. To one side of its brighter core, dark dust clouds appear as figures straining to break free. On the opposite edge a large dark cloud swirls around a glowing center and could be a harbinger of a binary star system in the making.

**Owl Nebula**

As the Northern Hemisphere eases into fall, Ursa Major’s popular Owl Nebula has definite autumnal appeal. Found below the bowl of the constellation’s famed Big Dipper asterism, the Owl Nebula is a planetary nebula that appears as a greenish disk marred by two dark voids that give the object its owl-like appearance. These “eyes” show up nicely in an 8-inch telescope, and the white dwarf that lurks between them reveals itself in a slightly larger telescope. Long-exposure photos will render a reddish outline around the green-hued core.
**Tarantula Nebula**

The final choice for this spooky space roundup can be found in the Southern Hemisphere’s Large Magellanic Cloud, which spills out into both the Dorado and Mensa constellations. From its post in the Dorado side, the mesmerizing Tarantula Nebula dominates the web of celestial wonders that pack this galaxy. This exceptional nebula is the largest and most active star-forming region in our Local Group of galaxies. Observations by NASA’s Hubble Telescope found the Tarantula Nebula teems with more than 800,000 stars and protostars. This nebula was also the location of Supernova 1987A, which lit up on February 23rd, 1987. Visible to the naked eye, this historic event was the closest supernova observed since the invention of the telescope.

**Ghost of Jupiter**

Another nebula with eye-like appeal is the Ghost of Jupiter. Located in the Hydra Constellation, which is visible from 54° North to 83° South, this planetary nebula can be captured in some telescopes as a blue-hued spherical cloud of gas and dust brewing around a central white dwarf. The fact that it is similar in size to our solar system’s giant planet Jupiter is what gives the nebula its name. Although it can be enjoyed with a small telescope, a larger one will show an intriguing outer halo.

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dark skies, enlightening experience

By MARY STEWART ADAMS
Guest Columnist

Humankind has always been thrilled and challenged by the discovery of new and never-before-seen objects and phenomena in the celestial world. Nowhere in contemporary culture is this experience more demonstrated than through the prolific work of David Levy, a brilliant research and discovery artist with a poet’s heart. Not content with mere binoculars and telescopes, David also makes use of poetry and prose to build a silver ladder into the night that enthusiasts of all ages may climb.

As an artist, David’s medium is the world of stars surrounding the Earth, where comets and asteroids beat out an irregular rhythm that only wants discovery in order to find its harmonious place within the catalog of human-cosmic encounters. To his credit is the discovery of more than 20 comets, 42 asteroids and innumerable poetic references from throughout the ages of man, joined with the stars through more than 30 books.

The Headlands International Dark Sky Park in Emmet County, Mich., recently enjoyed David’s talents and enthusiasm during an exciting evening program on his “Life and Hard Times as a Searcher of Comets.”

David set the stage with an inspiring poetry recitation that was followed by pieces of his biography woven through with historic references, music, stunning images and even clips from the 1960s television western series “Bonanza,” which specifically referenced the early life of astrophysicist Albert Abram Michelson, who became the first American to receive the Nobel Prize in Science in 1907.

The setting, though rugged, was ideal for the moist autumn air was hung with the comets out there that seek man, and in audience suggests that rather than man on Earth seeking comets out there, it is the comets out there that seek man, and in David Levy’s case, they have found a star.

Mary Stewart Adams is a star lore historian and director of programs for the Headlands International Dark Sky Park. As a storyteller dedicated to a humanities-based approach to dark sky advocacy, Mary has received numerous awards for her work and the opportunity to serve on the International Dark Sky Places Committee of the International Dark Sky Association. Her radio program, “The Storyteller’s Guide to the Night Sky,” airs Monday during Morning Edition on Interlochen Public Radio and can be accessed online.

David Levy, center, poses with Mary Stewart Adams and Bryan Shumaker at the Headlands International Dark Sky Park in Emmet County, Mich.
July 16, 1969: A defining moment

By DAVID H. LEVY

Sky's Up Editor in Chief

During the summer of 1968 I began working as an astronomy instructor at Camp Minnowbrook — a music, arts and science camp on the north shore of Lake Placid in the Adirondack Mountains of upstate New York. Lothar Eppstein and his wife, Paula, directed the camp. They ran it rather strictly, but during the three years I worked for them I grew to love them both.

On the morning of July 16, 1969, I was working my second year as an astronomy counselor. On that day the entire camp gathered in the third floor auditorium to watch the liftoff of Apollo 11, which carried astronauts Neil Armstrong, Buzz Aldrin and Michael Collins. This mission was the first American attempt to land on the Moon.

On that day, how many of us wondered what would happen next? Would humanity go to Mars? Romp across an asteroid, or explore a comet? On that night there seemed nothing our species could not do if we set our minds to it.

It is hard to recall the emotions that went through my mind at that moment; even harder to appreciate that when it shut down, the Eagle had just a few seconds of fuel left in its descent stage.

Two hours later I had a conversation with the head counselor, who had planned a typical program of evening activities. I suggested that we watch the first step on the Moon, placing one, then both feet on its surface and into history. "That's one small step for a man, one giant leap for mankind." I could not hold back tears as I beheld that moment. Eight years after President Kennedy gave us the Moon as a target and a challenge for the nation, and a mere eleven years after NASA was born, a human was there. On that night, as one-sixth of the world's population watched, humanity made its first steps onto a new world and into a new era.

On that day, how many of us wondered what would happen next? Would humanity go to Mars? Romp across an asteroid, or explore a comet? On that night there seemed nothing our species could not do if we set our minds to it. I imagine that most of us would provide a disappointing reply to this question. But it isn't all negative; for example, the Voyager spacecraft would sail past Jupiter, Saturn and Saturn's moon Titan. Its sister craft, Voyager 2, would accomplish the long hoped for Grand Tour of the outer planets, visiting the four giant worlds Jupiter, Saturn, Uranus and Neptune. And who would have imagined the great Pluto story? Early in 2006, New Horizons, perched atop an Atlas 5, soared aloft from the Kennedy Space Center all the way to Pluto. Just a few months after this marvelous launch, the International Astronomical Union would reclassify Pluto into something other than what I think really is.

We all probably could foretell that human explorers would build a Space Station housing astronauts and cosmonauts from lands all around the world. Actually, many, many accomplishments have occurred, just not the ones we hoped for on that magical late evening of July 20, 1969.
Not long ago, my daughter had surgery to remove her tonsils and was laid up at home recovering for several days. This necessitated the cancellation of an astrophotography trip I had planned to the desert. Instead, I setup the equipment in my backyard and shot an image of M42 through narrowband Hydrogen Alpha, Oxygen III and Sulfur II filters. One of the advantages of these filters is that they’re much less affected by light pollution and moonlight than broadband filters. I selected M42 because it’s my daughter’s favorite object and thought she might appreciate seeing it take shape as she recovered. Additionally, I hadn’t seen an image of M42 shot in what is known as the Hubble Palette. I was very pleased with the result.

This image was acquired using an Explore Scientific ED127 f/7.5 refractor telescope, an SBIG ST-8300M camera and a total of 19 hours of exposure time.

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"I wanted to attempt a very high resolution mosaic image with my Explore Scientific ED152 so I took on the very large field of the Rosette Nebula. The final image is composed of 100 hours of exposure time in a 4 panel mosaic. It captures the entire nebula at better than 1 arc second of resolution."

The Rosette Nebula

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M42 — The Orion Nebula

Faworski captured this wonderful image of the wispy NGC 6995 that lies in the Cepheus constellation. The nebula is a small part of the Veil Nebula, which is a vast and complex supernova remnant that is divided into three main parts – the Eastern Veil, the Western Veil and Pickering’s Triangle. The image was taken using an Explore Scientific ED127 f/7.5 refractor telescope, a QSI 583wsg camera, a Baader filter and a Paramount 1100S robotic telescope mount.

NGC 6995

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This image by Faworski showcases the reflection nebula VdB 152, which lies atop the trailing Barnard 175 Bok Globule in the Cepheus constellation. The image was taken using an Explore Scientific 208mm f/3.5 Newtonian telescope, a QSI 583wsg camera, a Baader filter and a Paramount 1100S robotic telescope mount.

VdB 152
the art of astronomy

Astrophotographer: Chuck Kimball

Kimball captured this photo of the Draco Dwarf spheroidal galaxy in June 2014 with an Explore Scientific 208mm Newtonian outfitted with an ES coma corrector and a Canon XT/350D DSLR modified by Hutech Astronomical Products. The image is a stack of 60 five-minute exposures at ISO 800 and 1600.

NGC 2647

“I was inspired to work on this object by an image from Bernhard Hubl with the European team CEDIC. The driving force of the nebulosity is not clear but is likely strongly affected by HD 64315, the brighter star in S311, the lighter portion to the right of center. There are two cataloged open clusters near the center.”

The image, which was taken in February, was acquired using an ES 208mm Newtonian with an ES coma corrector, a Canon XT/350D DSLR modified by Hap Griffin and a custom saddle on a modified Meade LX200GPS fork. Total exposure time was 110 minutes.

the art of astronomy

Astrophotographer: Jack B. Newton

Newton showcases the swirling Whirlpool Galaxy, which is interacting with a smaller dwarf galaxy known as NGC 5195 in the Canes Venatici constellation. The image was taken with Explore Scientific’s ED152 refractor telescope, an SBIG 8300 CCD camera and a total of 100 minutes of exposure time.

The Sun

The tumultuous personality of our star resonates in this photo by Newton. He captured this image using a Coronado SolarMax II 90mm double stack solar telescope with an H-alpha filter and a DMK 31 AUO CCD camera. It was processed with Registax and Adobe Photoshop.

Draco Dwarf

“I was inspired to work on this object by an image from Bernhard Hubl with the European team CEDIC. The driving force of the nebulosity is not clear but is likely strongly affected by HD 64315, the brighter star in S311, the lighter portion to the right of center. There are two cataloged open clusters near the center.”

The image, which was taken in February, was acquired using an ES 208mm Newtonian with an ES coma corrector, a Canon XT/350D DSLR modified by Hap Griffin and a custom saddle on a modified Meade LX200GPS fork. Total exposure time was 110 minutes.
With a universe of options to explore, it can be difficult to track what awe-inspiring treasures are visible in your sky each month. To help guide your explorations throughout the year, Sky’s Up is providing this moon calendar and the following collection of seasonal star maps created by noted celestial cartographer Wil Tirion. Based in The Netherlands, Tirion has been crafting stars maps since the 1970s and became a professional uranographer shortly after the publication of his highly regarded Sky Atlas 2000.0 in 1981. To learn more about Tirion and his work, click here.

The phase date & time is for UT (Universal or Greenwich Time). Depending on your time zone you have to add or distract a number of hours.

(USA: Eastcoast –5 hours; Westcoast –8 hours)
the key to your sky
CREATED BY Wil Tirion

WINTER SKY
For observers at 10° to 30° northern latitudes

WINTER SKY
For observers at 40° to 60° northern latitudes
the key to your sky

For observers at 10° to 30° northern latitudes

SPRING SKY

For observers at 40° to 60° northern latitudes
the key to your sky

created by Wil Tirion

the key to your sky

created by Wil Tirion

SUMMER SKY
For observers at
10° to 30° northern latitudes

SUMMER SKY
For observers at
40° to 60° northern latitudes
“Watching even the most remarkable movies for a second time can be sometimes boring but there is something in celestial scenes and their contrast to terrestrial foregrounds that always looks new to me! And perhaps to all other night sky enthusiasts. Rising or setting of the full moon, an immensely watched natural scene, still inspires millions around the world every month.”

— Babak Tafreshi