SkyWAAtch

Comet ISON

Rick Bria took this picture of Comet ISON at 5:15am on November 11th from June Hill Observatory using a TV101 refractor and Canon 60Da camera (eight one-minute exposures stacked in Deep Sky Stacker using comet mode and then processed in Photoshop CS5). Notes Rick: Because the comet moved relative to the stars during data acquisition, and since the stack was aligned on the comet, the stars trail out into lines in the image. This gives the impression that the comet is quickly streaking through the sky, but that is not the case. I had interference from a tree and had to wait until the comet cleared most of the branches. Sadly, by the time the comet cleared the branches twilight had begun. The brightening sky reduced contrast in the tail.

Comet ISON was much dimmer than predicted to be at this time. It brightened considerably since this picture was taken as it plunged closer toward the Sun and volatiles sublimated off its surface (editor's note: see page 11 for an update).

In This Issue . . .

Events for December 2013

WAA December Lecture and Annual Meeting

"The History of the Telescope"
Friday December 6th, 7:30pm
Lienhard Lecture Hall, Pace University
Pleasantville, NY

Few, if any, inventions have played as crucial of a role as the telescope in defining mankind's place in the Universe. On December 6th, Al Witzgall will speak on the history of this most important invention. Mr. Witzgall holds a Bachelor's degree in Earth Sciences from Kean University. He is an active long-term member of the Amateur Astronomers, Inc. of Cranford, NJ, and is a past president of that organization. He is also active at the New Jersey Astronomical Association in High Bridge, NJ, serving there as its Vice-president. He is currently a Senior Optician for Fastpulse Optics in Saddle River, NJ. His career in optics started with building telescopes in his basement during his high school years. In 1977, one of them, a 10-inch reflector, took First Award at Stellafane. Directions and Map.

A brief annual meeting will be held before the lecture (election of officers and a membership report).

Upcoming Lectures

Lienhard Lecture Hall,
Pace University Pleasantville, NY

On January 10th, Dr. Michael Tuts, a physics professor at Columbia University, will present: "The Higgs Boson has been Discovered - What is it, and are we Done?" Free and open to the public.

Meadow Picnic Area,
Ward Pound Ridge Reservation,
Cross River, NY

There will be no public Starway to Heaven observing events in December, January or February. Starway to Heaven events will resume in March 2014.

New Members. . .

Dennis Galcik - Bronx
Kevin Shea - Ossining
Kevin Mathisson - Millwood
Mauricio Alvarez - Bronx
Ben Wagner - Pleasantville

Renewing Members. . .

Larry and Elyse Faltz - Larchmont
Bob Kelly - Ardsley
Warren Lindholm - Cortlandt Manor
Scott Nammacher - White Plains
Al Forman - Croton-on-Hudson
Michael Rinaldi - Scarsdale
Sharon and Steve Gould - White Plains
Erik Esposito - Bronxville

WAA APPAREL

Charlie Gibson will be bringing WAA apparel for sale to WAA meetings. Items include:

- **Caps and Tee Shirts, $10**
- **Short Sleeve Polos,**
- **Navy hoodies for $22.**

Call: 1-877-456-5778 (toll free) for announcements, weather cancellations, or questions. Additional information for members will be provided by Eblasts. Also, don't forget to periodically visit the WAA website.

Pinwheel Galaxy

Courtesy of Olivier Prache is this image of the M33, the Pinwheel galaxy in Triangulum taken through a 12.5' Hyperion astrograph with a ML16803 camera (a little over 9 hours exposure, processed with PixInsight and post processed with Photoshop).

Almanac

For December 2013 by Bob Kelly

Now we are finding out if Comet ISON held itself together after its death-defying plunge so close to the Sun. Perhaps the first week of December will bring us a celestial fan dance in the morning sky, if ISON's remains spread out in multiple tails arcing into the morning sky. Of course, if ISON fell apart on its inbound trip, there may be none of ISON left to see. Check the web to find out.

What's the sky going to look like on Christmas Eve and the following eves and morns? Once the twilight ends, face north, and almost overhead the Milky Way will spread out to your left and your right, a ribbon of delicate light wrapping the gift of the night sky. This soft band of stars stretches from Altar to your left to Betelgeuse to your right. Your gift comes monogrammed, if you name has an "M" in it as Cassiopeia caps the package, highest above you. Lunatics (like me) will have to look to the morning sky, where the setting Sun makes craters standout on a half-moon topped with a festive reddish Mars on top.

Bright object fans will delight in Jupiter rising just after sunset, obligingly plump like a Christmas goose. Unlike the goose, no animals will be harmed by shooting at Jupiter and its fine four bright moons with your camera.

If you can find Venus, low in the evening twilight sky, setting only 1½ hours after the Sun, your telescope or good binoculars will show an elongated crescent Venus, appearing to extend from tip to tip larger than Jupiter! Follow Venus all month in the southwest sky as it gets larger passing Jupiter's width by mid-month. Unlike most celestial objects, Venus' phase is easier to see when the sky is brighter.

Another famous bright object makes a return to our skies with Saturn low in the southeastern morning sky. From our point of view in the inner solar system, Saturn looks tiny compared to its planetary siblings at one-third the width of Jupiter. Saturn's rings add some girth to the planet, tipped 21 degrees toward Earth, making a pretty picture. Mars, in a telescope, is only one-third the apparent size of Saturn, which may be a disappointment to the casual viewer, but Mars' north polar cap is tipped a bit toward Earth. If the jet stream is not roiling the sky overhead, the late winter polar cap might be visible in contrast with the ocher soil of the rest of the planet. As Mars' disc gets larger as we approach our closest approach in April, the polar cap will be shrunken in the Martian spring sun, and will be harder to see then.

The more distant planets are moving out of the evening sky. Uranus sets by midnight by the end of the month. Neptune beats Uranus to the horizon, making right after dark the best time to view our solar system's outliers.

Have you noticed your shadow getting longer and lining up down your office hallway right after sunrise? Watch your sunrise shadow lengthen in the hallway until around the 5th when sunrise in Manhattan will line up with the cross streets. If your building is lined up with the street grid, the sunrise sunlight can pass straight through the building and out the other side. The earliest sunset occurs on the 7th, making the sunset noticeably earlier by the end of the year. Sunrise gets later until early January, making it a little easier to get up to see December's morning sky sights.

The Moon keeps the evening watch for the first half of the month and occupies the morning side of night in the second half. The Full Moon is high in the midnight sky, looking really far away. This month, it is really far away, the furthest away full moon in 2013. Even then, it washes out the nearby winter star clusters, competing with nearby Jupiter for attention on the 17th and 18th. Then, Gemini appears to kick the Moon around like a soccer ball.

You don't have to wait long for the International Space Station appearing shortly after sunset from the 7th through the end of the month.

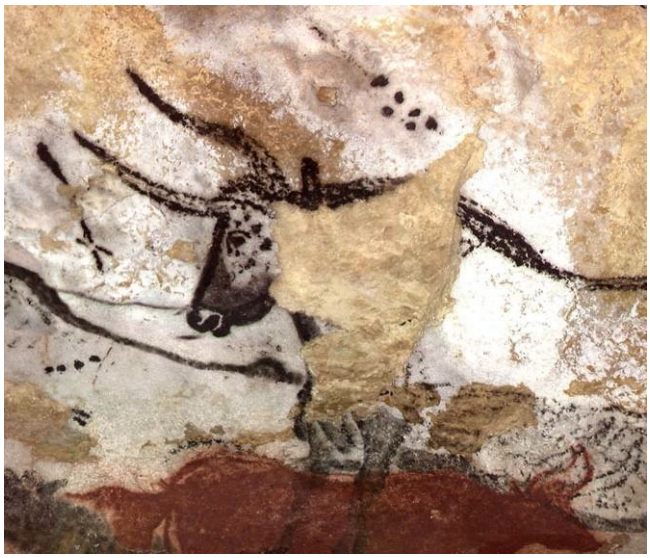
Westchester
Amateur Astronomers

The Pleiades: History, Art and Science
by Larry Faltz

The Pleiades, photographed with the 48-inch Schmidt reflector at Mt. Palomar

Rising in the eastern sky a few hours after dark in the early fall, the Pleiades, fabled in astronomical and cultural history, marks the end of summer even though the so-called Summer Triangle of Vega, Deneb and Altair still dominates the zenith.

The Pleiades has been in human consciousness as far back as we can trace. The oldest pictorial representation may be a cave painting at Lascaux, in France. I've always felt that the Lascaux paintings look too contemporary to be really prehistoric, and I can't look at them without sniffing a potential hoax. However, the site has been certified as authentic and the paintings are at least 15,000 years old. In one of them, sitting above the image of a bull, six dots are taken by some observers to represent the Pleiades above the constellation Taurus. Certainly the celestial bull, with the Hyades for horns, is one of the oldest and most culturally widespread of the constellations.



Cave painting at Lascaux, France

The Pleiades may be represented in the Indus Script, an as yet undeciphered pictogram language from about 2600 BC. Another ancient visual representation is the Nebra Sky Disk, a Bronze Age object discovered in 1999 and now housed in the Sachsen-Anhalt State Museum for Prehistory in Germany. This foot-wide bronze plaque, dated to about 1600 BC, shows gold symbols thought to represent the sun or full Moon, a crescent moon and stars, seven of which form a cluster that's been suggested to be the Pleiades.

The Nebra Sky Disk

The Pleiades cluster is near the ecliptic, which means that every populated area on Earth has a view of them. The brightest deep sky object, they've been named and mythologized by every culture. To the ancient Egyptians, they represented the mother goddess Neith. To the Maori of New Zealand, a culture that evolved in complete isolation from the West until the 18th century, they are Matariki, a mother and her six daughters. To the Tamil of Ceylon they are the wet nurses of the war god Skanda, one of many avatars of the cluster in ancient Indian subcontinent cultures and religions. There is a substantial (but not universal) consistency in giving them female attributes.

Pleiades (Πλειαδεσ) is their Greek name. The derivation of this word is uncertain. The writer Robert Graves suggested that the root comes from the Greek word for "to sail" or a word meaning "many," while the name used by the Greek poet Pindar (518-438 BC) is Peleiades, meaning "a flock of doves."

The classic Greek legend (one of several variations in Greek mythology) is that they were the seven daughters of Atlas, the Titan who held up the sky, and Pleione, the protectress of sailing. The hunter Orion was enamored of them and pursued them until Zeus turned them into a flock of doves, which he placed in the heavens. The names we use for the brightest stars come from this legend.

A wonderful Kiowa myth parallels the Greek story. Seven maidens were threatened by giant bears. The Great Spirit created the Devil's Tower, in Wyoming, to place them beyond the bears' reach. But the bears climbed the mesa, gouging out the Tower's well-known vertical grooves with their claws. So the Great Spirit placed the maidens in the sky, permanently out the bears' reach. Among other Native American myths is a Mono Indian tale that they are a group of wives who were fond of eating onions and were thrown out of their homes by their angry husbands, subsequently wandering into the sky. To the practical and economical Japanese, they are called "Subaru", not the name of beings but merely meaning "gathered together" and of course we are familiar with them as the name and insignia of the car manufacturer. As a loyal amateur astronomer, I have 2 Subarus (following 15 years of owning Saturns, 4 in all).

The Pleiades' location on the celestial globe means that after sunset they rise in the fall and set in the spring, establishing a rhythm for the change of the seasons. More than one culture uses them as an alarm clock for agricultural activity. In the earliest written Greek text, the *Works and Days* of the poet Hesiod (~700 BC), these relationships are laid down:

> When the Pleiades, daughters of Atlas, are rising, begin your harvest, and your ploughing when they are going to set.

The Mediterranean sailing season runs from March to November, so it starts when the Pleiades are setting and ends when they are rising. This may have been the origin of the myth relating the stars to the demi-goddess Pleione and to Graves' assertion of a nautical origin for the name. In *Works and Days*, Hesiod gives this advice:

> And if longing seizes you for sailing the stormy seas, when the Pleiades flee mighty Orion and plunge into the misty deep and all the gusty winds are raging, then do not keep your ship on the wine-dark sea but, as I bid you, remember to work the land.

There are a vast number of references to the Pleiades in classical literature. In the *Iliad*, created a couple of

centuries before Hesiod but existing only as an oral tradition until it was written down around Hesiod's time, Homer describes the god Hephaestus forging and decorating Achilles' shield:

> He made the earth upon it, and the sky, and the sea's water, and the tireless sun, and the moon waxing into her fullness, and on it all the constellations that festoon the heavens, the Pleiades and the Hyades and the strength of Orion and the Bear, whom men give also the name of the Wagon, who turns about in a fixed place and looks at Orion and she alone is never plunged in the wash of the Ocean.

Here's a charming fragment by the female poet Sappho (~590 BC):

> The sinking moon has left the sky,
> The Pleiades have also gone.
> Midnight comes--and goes, the hours fly
> And solitary still, I lie.

In the Bible, the cluster is mentioned in Amos and twice in Job, most eloquently when Job muses on the powerlessness of man in the presence of God:

> It is God who removes the mountains, they know not how, when He overturns them in His anger;
> Who shakes the earth out of its place, and its pillars tremble;
> Who commands the sun not to shine, and sets a seal upon the stars;
> Who alone stretches out the heavens, and tramples down the waves of the sea;
> Who makes the Bear, Orion and the Pleiades, and the chambers of the south;
> Who does great things, unfathomable, and wondrous works without number.
> Were He to pass by me, I would not see Him; were He to move past me, I would not perceive Him.
> Were He to snatch away, who could restrain Him? Who could say to Him, 'What are You doing?'
>
> (*New American Bible*, Job 9:5-12)

These passages reflect the visual prominence of the Pleiades, their near-universal recognition among the populace, and the ease in which they can carry metaphorical meaning.

In his odd and rhythmically complex 1835 poem *Locksley Hall*, Tennyson writes

> Many a night from yonder ivied casement, ere I went to rest,
> Did I look on great Orion sloping slowly to the West.
>
> Many a night I saw the Pleiads, rising thro' the mellow shade,
> Glitter like a swarm of fire-flies tangled in a silver braid.

Two more recent cultural references are in opera. At the end of Act I of Verdi's *Otello*, the Moorish admiral and his wife, the ill-fated Desdemona, share what turns out to be their last happy moments. To transcendentally beautiful music, Verdi sets these lines:

> **OTELLO**
> Un bacio. . .ancora un bacio,
> Gia la pleiade ardente al mar discende.
> **DESDEMONA**
> Tarda e la notte.
> **OTELLO**
> Vien. . .Venere splende.
>
> [Othello: A kiss, another kiss. The fiery Pleiades descend toward the sea. Desdemona: The night is late. Othello: Come. Venus is shining.]

In Benjamin Britten's 1946 opera *Peter Grimes*, the tragic story of a misfit English fisherman (and undoubtedly the greatest opera in the English language), the misunderstood Grimes sings an aria reflecting on man's helplessness, perhaps echoing Job:

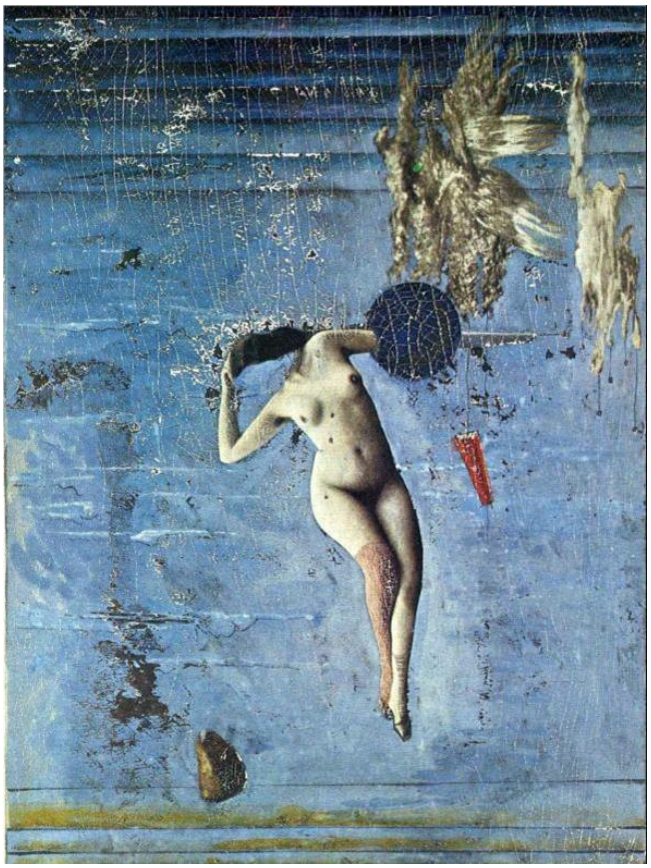
> Now the great Bear and Pleiades where earth moves
> Are drawing up the clouds of human grief,
> Breathing solemnity in the deep night.
> Who can decipher,
> In storm or starlight,
> The written character
> of a friendly fate –
> As the sky turns, the world for us to change?
> But if the horoscope' s bewildering
> Like a flashing turmoil of a shoal of herring,
> Who can turn skies back and begin again?

Needless to say, so prominent an astronomical feature as the Pleiades interests artists as well as poets. The figurative representation of the Pleiades as a group of women can be seen in a number of paintings. British artist Henry Howard painted them as weightless in the clouds, while American painter Elihu Vedder showed the seven sisters in a wild dance, spinning the stars overhead on lanyards, echoing Tennyson. Howard's painting is in Sir John Soane's Museum in London, an odd and fascinating venue that's kept exactly as architect and collector Soane left it when he died in 1837. The Metropolitan Museum owns Vedder's painting, although I've never seen it on display there.

Henry Howard, Night with the Pleiades (1834) (13x68 in.)

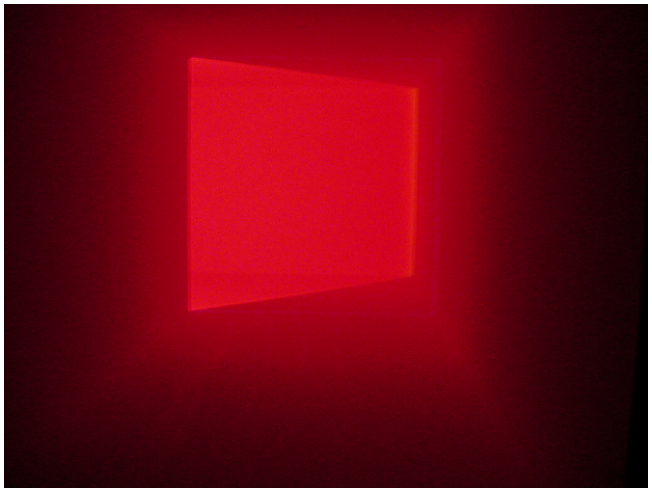
Elihu Vedder: The Pleiades (1885) (24x37 in.)

German artist Max Ernst, a founder of Dadaism and surrealism, has a completely different, more tragic take, a view that might be expected following the devastation of World War I.



Max Ernst, Pleiades (1920) (collage, 7x12 in.)

Contemporary artist James Turrell (b. 1943) creatively explores the interaction of light and space. He recently had a very successful show at the Guggenheim Museum. His "dark pieces" explore human vision at night, with the goal of creating "a space in which the viewer experiences a blurring of the boundary between what is seen outside oneself and what is seen in the mind's eye." These installations consist of darkened rooms with projections. The viewer enters and adjusts to the dim light over time. His first one was called "Pleiades." It doesn't bear much resemblance to either the star cluster or its mythological avatars, but it does achieve a recall of the sensation of getting accommodated to the glow of the stars on a dark night.



James Turrell, Pleiades

Perhaps the most important graphic representation of the cluster was not by an artist, but by Galileo Galilei, the founder of modern science, in the pamphlet *Sidereus Nuncius* (Starry Messenger) published in March 1610. This is the work that describes his telescopic observations of the moon, the stars and Jupiter. His view of the Pleiades in the fall of 1609 showed more than the seven stars of history and legend. This helped disprove the ancient and theologically orthodox concept that the heavens were perfect and unchanging.

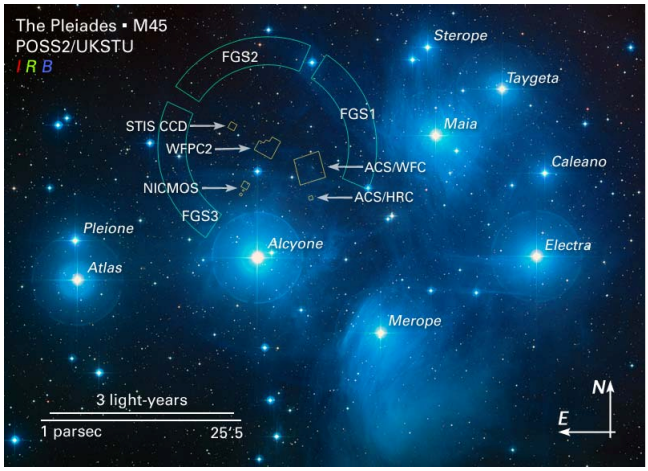
Galileo's drawing of the Pleiades (1610)

Galileo describes his view with the absolute objectivity of a scientist, avoiding any speculation

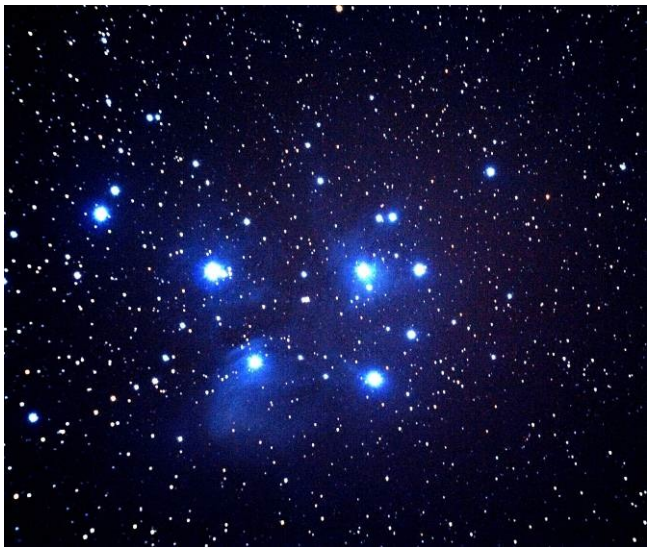
about the meaning of his observations. He knew his findings would speak for themselves.

> I have depicted the six stars of Taurus known as the Pleiades (I say six, inasmuch as the seventh is hardly ever visible) which lie within very narrow limits in the sky. Near them are more than forty others, invisible, no one of which is much more than half a degree away from the original six. I have shown thirty six of these in the diagram; as in the case of Orion I have preserved their intervals and magnitudes, as well as the distinction between old stars and new.

The brightest star, Alcyone, is magnitude 2.86 but the entire cluster registers on our eyes as magnitude 1.6. It's not dark enough, and older adult eyes are usually not good enough, to resolve all of the brightest members of the cluster. In fact there are 9 stars brighter than 6th magnitude and there are probably over 1,000 stars gravitationally bound in the group. The brightest part of the cluster is over a degree in diameter, 8-10 light years across at its distance of 400 light-years. The Schmidt photograph at the top of this article is overlaid below with the Hubble Space Telescope imaging fields. It's a good reference for the stars in the Pleiades and also to appreciate the field of view of the various Hubble cameras.

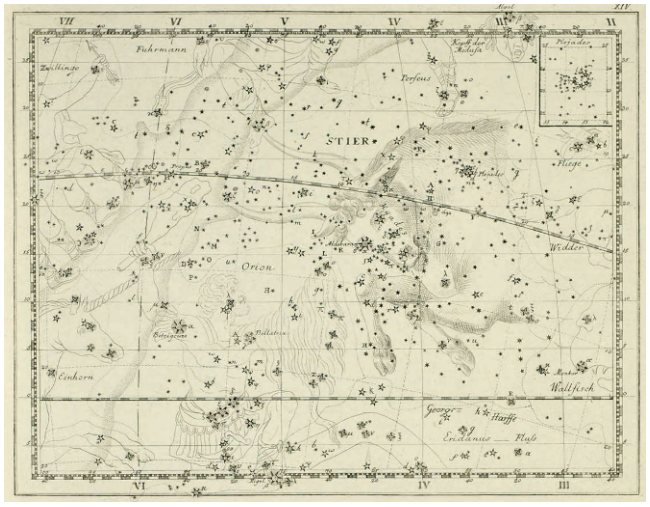


The cluster is made up of hot, blue B-type stars (surface temperatures between 10,000 and 30,000 degrees Kelvin) that are between 75 and 150 million years old. Many brown dwarfs have been detected with infrared observations. The reflection nebula, a favorite astrophotography target, is actually a band of dust through which the stars are passing, not the material from which the stars condensed. Stellar radiation pressure would have dispersed any material left over from the stars' birth. The nebulosity around Merope was first glimpsed in 1859 by Wilhelm Tempel using just a 4-inch refractor, so in a truly dark site telescopes owned by amateurs ought to be capable of reproducing this observation. The nebulosity is tough to see in our area because of light pollution. But even a small telescope with a properly used camera can image the dust, as shown by WAA member John Paladini, who photographed the cluster in 2008 from his home in Mahopac, NY using an 80 mm refractor and a DSLR.



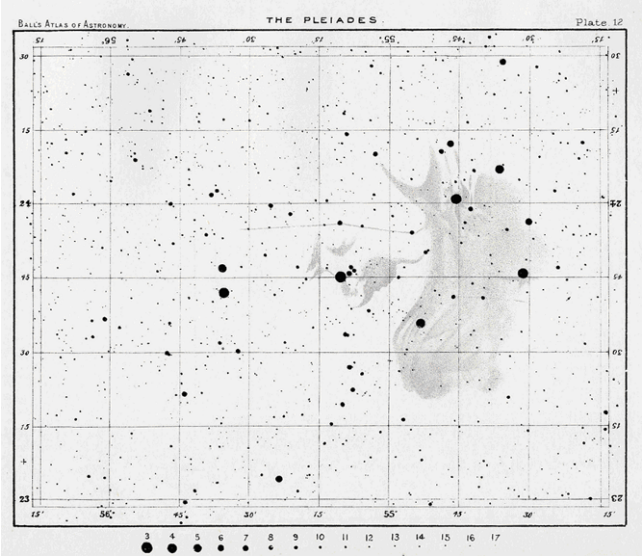
John Paladini 80 mm refractor

Star maps are another form of astronomy-art (see my article in the October 2013 newsletter). In star maps published before the nebulosity was discovered, the Pleiades are generally shown as a small group of stars on the shoulder of Taurus. Bode's influential *Vorstellung der Gestirne,* first published in 1782, shows the cluster *in situ* as well as featuring an inset map at higher magnification, apparently the first time this detail appeared in a celestial map.



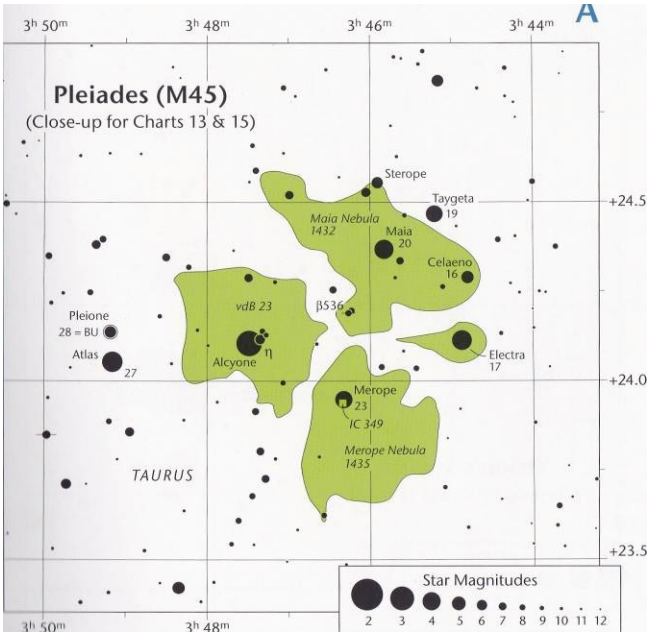
Taurus, from the 1805 edition of Bode's *Vorstellung der Gestirne*. Note the Pleiades inset in the upper right corner.

Cartographers have taken two approaches to the representation of the nebulosities on star maps. *Ball's Atlas of Astronomy (1892)* tries to show some detail in the clouds.



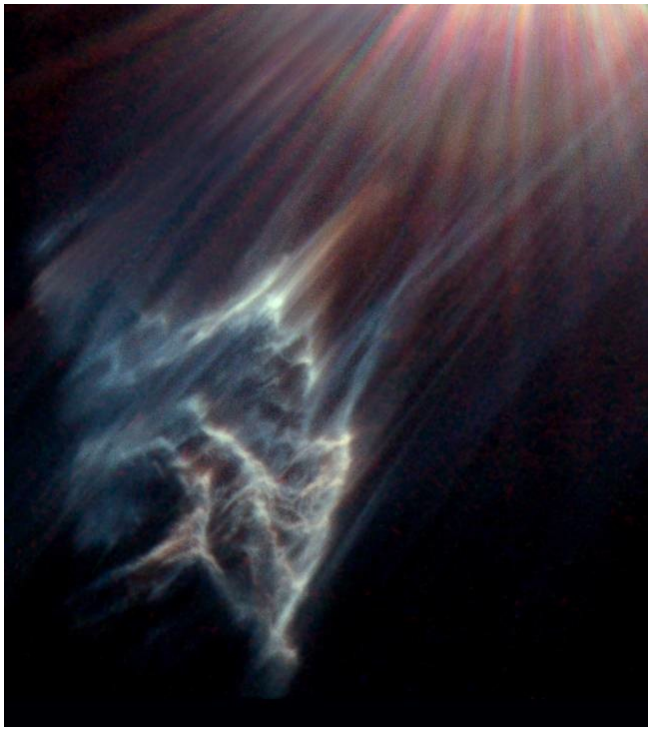
Ball's Atlas of Astronomy

Many modern maps just outline the extent of the nebular regions, such as this scanned example from Roger Sinnott's *Sky and Telescope Pocket Sky Atlas*.



S&T Pocket Star Atlas detail map of the Pleiades

Modern telescopes have been trained on the cluster for research purposes. In addition to revealing detailed spectra of faint stars and detecting many brown dwarfs, Hubble provided detailed images of the interstellar gas cloud that forms the nebula.



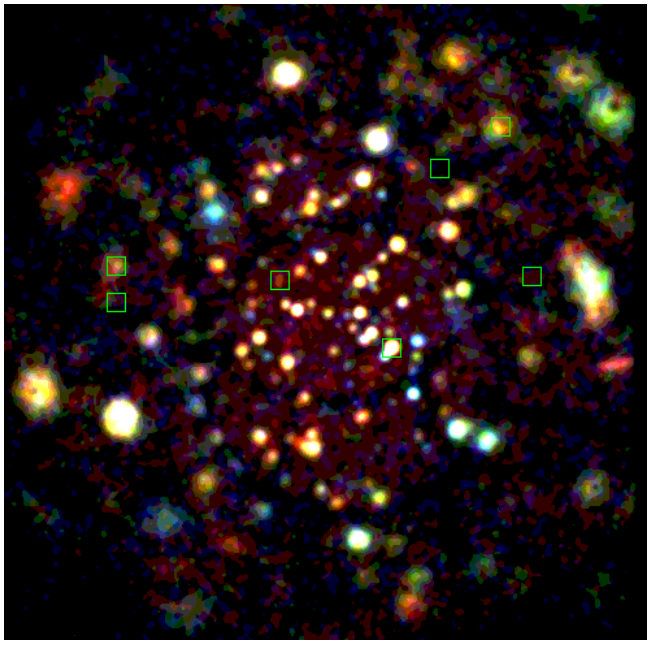
Hubble image of part of the Merope nebula (WFPC2, 1999)

Other space telescopes with spectral ranges beyond the visual have been trained on the Pleiades. An infrared image from Spitzer shows an intense amount of radiation from the dust as well as a large number of smaller stars and even some brown dwarfs.

Spitzer (Infrared)

In the 1990's, the ROSAT X-ray space telescope found over 170 X-ray emission sources in the cluster.

These are very hot, very young stars that must be rotating rapidly. They are clearly distinct from the optically bright members of the cluster.



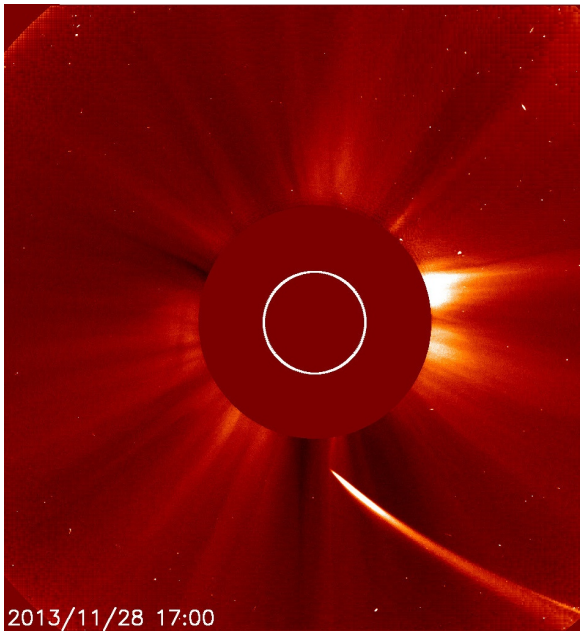
ROSAT X-ray (green squares=7 optically brightest stars)

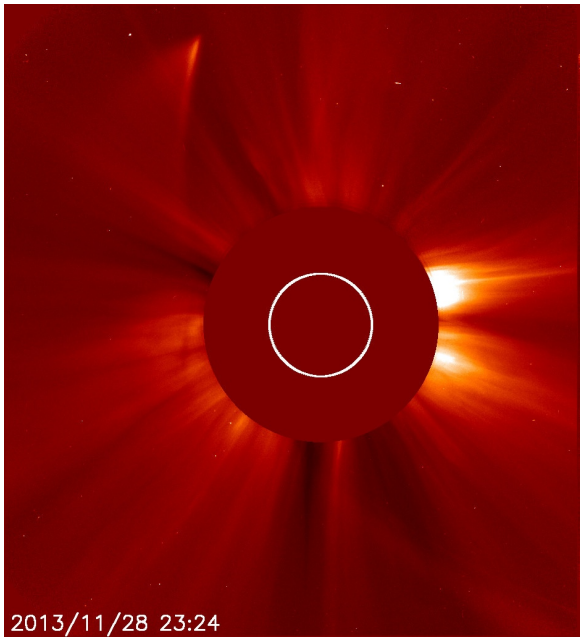
Because the Pleiades are so close to the ecliptic, conjunctions with the moon, planets and even comets can occur, and lunar occultations may be observed from time to time. Because of the cluster's 2-degree extent, a lunar occultation takes several hours, since the moon travels about 1 arc-minute for every 2 minutes of time. The tilt of the lunar orbit relative to the ecliptic (which determines the Saros cycles of solar eclipses) means that occultations do not occur evenly but come in groups. There was a series of lunar occultations between 2004 and 2010, and the next series will take place between 2023 and 2030.

Conjunctions of the inner planets are rare. Since Mercury is never more than 28° and Venus never more than 47° from the sun, visible conjunctions can only occur in spring or fall when the planet is on the night-time side of the rising (fall) or setting (spring) sun and in the optimal position in its orbit. For Venus, this occurs about every 8 years. The last Venus conjunction was on April 4, 2012. Visible Mercury conjunctions are far less frequent. Conjunctions of the outer planets occur relative to their orbital periods, but visibility obviously depends on where the sun is when the planet lines up with the cluster. Mars arrives in the area every 1.9 years and will be there in mid-May 2015, but it will be a tough view because of the sun. Jupiter will be about 5 degrees from the Pleiades in late May 2024 but again the sun will wash out the view. A month earlier, when the Pleiades will still be visible just after dusk, the planet will be 12 degrees away, not much of a conjunction either visibly or photographically. Saturn will be arriving in the area in early 2030 and but will be south of the ecliptic, making a close approach of only about 6 degrees in early April. It will go past and then retrograde early in 2031, getting within 7 degrees. Uranus will pass slowly through the area within 4 degrees of the cluster between 2025 and 2027. Neptune won't be around until in May 2053, when it will be within 3 degrees, but visibility will be difficult because of the sun. It will be a little further away the following winter, but will be viewable in darker conditions.

Venus approaching the Pleiades (APOD, 4/2/12)

The Pleiades has inspired poets and composers, intrigued scientists, and excited even causal observers but it also has stimulated a lot of ridiculous New Age babble. One particularly silly example is LightConnection.org, which claims, "Although we live on Earth, many of us originated on other planets, in other parts of the Universe. This is why many of us feel 'out of place' or like we belong somewhere else." One of the "planets" cited is the Pleiades, and "Those who have Pleiades as their planetary origin are sensitive, loving and kind. There is a deep, abiding desire for peace and happiness for all. If one from Pleiades were asked what do you want out of life? They would likely say, 'to be happy.'" All of this stuff would be entertaining if it wasn't so profoundly stupid and infantile. Anyway, you don't have to go to or come from the Pleiades to have this view of life: our own earthly philosopher Aristotle explained in the *Nicomachean Ethics*, one of the most profound works of human thought ever written, that happiness is the natural goal of life. Read the *Ethics*. Then take a look at the beautiful Pleiades, and be happy!



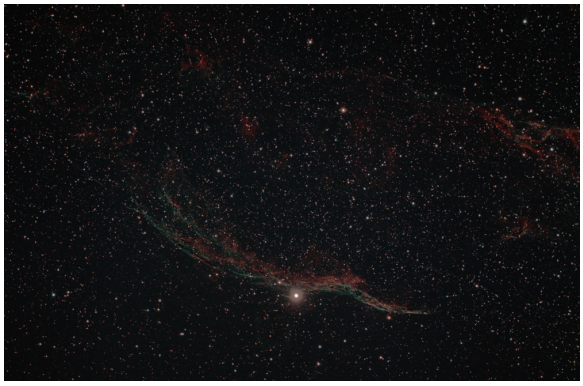


Comet ISON Update

Sun-grazing Comet ISON reached perihelion, its closest approach to the Sun on November 28, at 18:45 UT. The comet passed just over 1 million kilometers above the solar surface, a distance less than the diameter of the Sun. These two panels follow ISON before (upper) and after (lower) its close approach, imaged by the LASCO instrument onboard the Sun staring SOHO spacecraft. Overwhelming sunlight is blocked by LASCO's central occulting disk with a white circle indicating the Sun's position and scale. The bright comet is seen along its path at the bottom of the before panel, but something much fainter exits near the top of the after panel, potentially a dust tail reforming from the debris left from ISON's perihelion passage.

Subsequent reports suggest that a small part of the Comet's nucleus may of survived the close approach although debris predominates. As we go to press, it appears unlikely the Comet will be ever be discernible by visual observers and questionable whether it will provide amateur telescopes with a worthwhile target. Check the *WAA website* for further information.

Image Credit: NASA, SOHO



Witch's Broom

Rick Bria captured this image of the Witch's Broom Nebula at the Mary Aloysia Hardey Observatory at the Convent of the Sacred Heart. Nebulae are often named after objects they resemble; in this case the nebula resembles a broom. It is Located 1400 light years away in the constellation Cygnus. the Swan. The image is a 25 stack of 3 minute sub-exposures taken through a TeleVue 76mm refractor with a Canon 60Da camera. The data was processed in Deep Sky Stacker software and PhotoshopCS6.

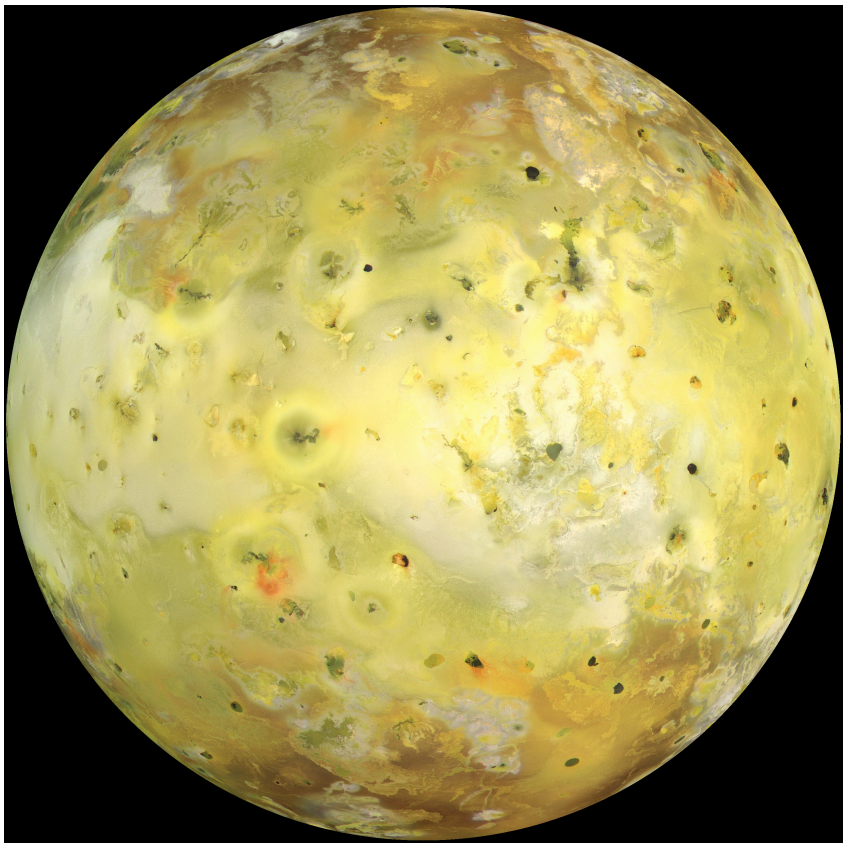
The Most Volcanically Active Place is Out-of-this-World!
by Dr. Ethan Siegel

Volcanoes are some of the most powerful and destructive natural phenomena, yet they're a vital part of shaping the planetary landscape of worlds small and large. Here on Earth, the largest of the rocky bodies in our Solar System, there's a tremendous source of heat coming from our planet's interior, from a mix of gravitational contraction and heavy, radioactive elements decaying. Our planet consistently outputs a tremendous amount of energy from this process, nearly three times the global power production from all sources of fuel. Because the surface-area-to-mass ratio of our planet (like all large rocky worlds) is small, that energy has a hard time escaping, building-up and releasing sporadically in catastrophic events: volcanoes and earthquakes!

Yet volcanoes occur on worlds that you might never expect, like the tiny moon Io, orbiting Jupiter. With just 1.5% the mass of Earth despite being more than one quarter of the Earth's diameter, Io seems like an unlikely candidate for volcanoes, as 4.5 billion years is more than enough time for it to have cooled and become stable. Yet Io is anything but stable, as an abundance of volcanic eruptions were predicted before we ever got a chance to view it up close. When the Voyager 1 spacecraft visited, it found no impact craters on Io, but instead hundreds of volcanic calderas, including actual eruptions with plumes 300 kilometers high! Subsequently, Voyager 2, Galileo, and a myriad of telescope observations found that these eruptions change rapidly on Io's surface.

Where does the energy for all this come from? From the combined tidal forces exerted by Jupiter and the outer Jovian moons. On Earth, the gravity from the Sun and Moon causes the ocean tides to raise-and-lower by one-to-two meters, on average, far too small to cause any heating. Io has no oceans, yet the tidal forces acting on it cause the world itself to stretch and bend by an astonishing **100 meters** at a time! This causes not only cracking and fissures, but also heats up the interior of the planet, the same way that rapidly bending a piece of metal back-and-forth causes it to heat up internally. When a path to the surface opens up, that internal heat escapes through quiescent lava flows and catastrophic volcanic eruptions! The hottest spots on Io's surface reach 1,200 °C (2,000 °F); compared to the average surface temperature of 110 Kelvin (-163 °C / -261 °F), Io is home to the most extreme temperature differences from location-to-location outside of the Sun.

Just by orbiting where it does, Io gets distorted, heats up, and erupts, making it the most volcanically active world in the entire Solar System! Other moons around gas giants have spectacular eruptions, too (like Enceladus around Saturn), but no world has its surface shaped by volcanic activity quite like Jupiter's innermost moon, Io!



Io. Image credit: NASA / JPL-Caltech, via the Galileo spacecraft.

Learn more about Galileo's mission to Jupiter: http://solarsystem.nasa.gov/galileo/.

Kids can explore the many volcanoes of our solar system using the Space Place's Space Volcano Explorer: http://spaceplace.nasa.gov/volcanoes.