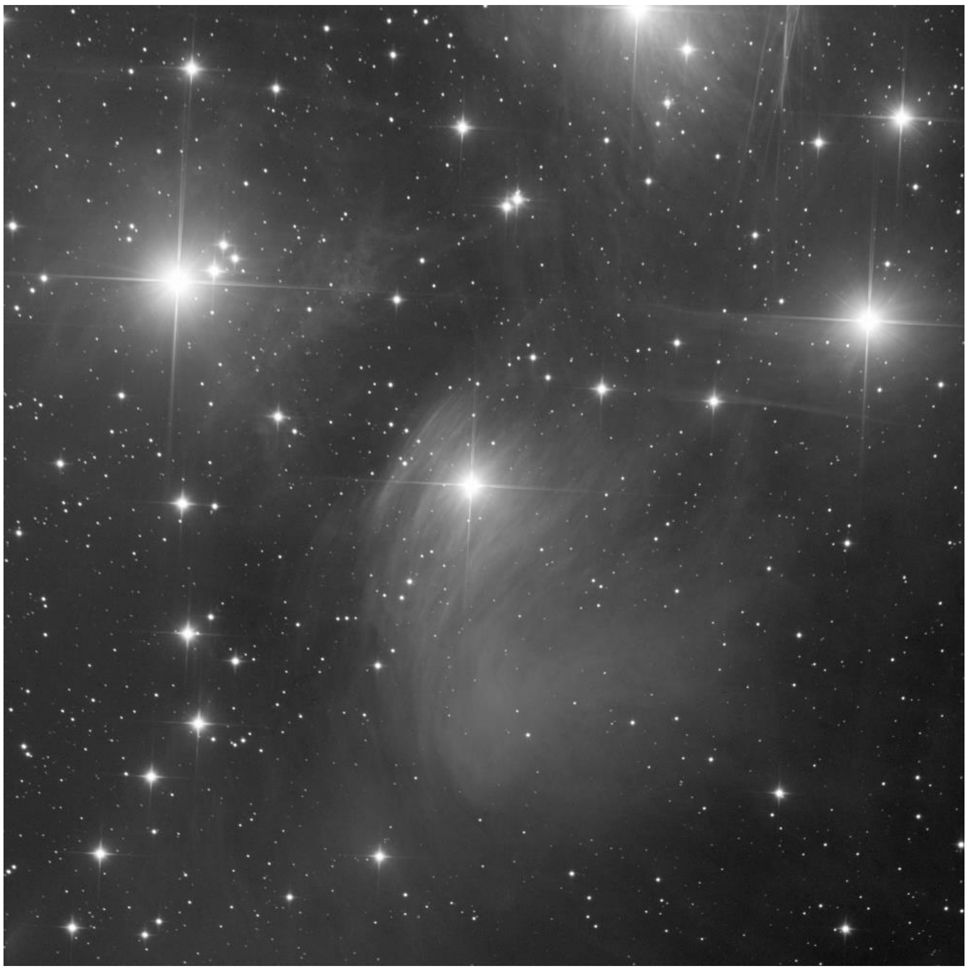
SkyWAAtch



A Successful Test

Olivier Prache provided this impressive test image of the Pleiades star, Merope, and its accompanying nebulosity using an ML16803 camera and 12.5" Hyperion astrograph. Notes Olivier: I went for long exposure (30 minutes per frame) and a high level of image stretch to get faint details out since the noise was low due to the longer exposure time. I like the somewhat surreal appearance of the image. This is Merope after 1.5 hours (remarkable level of detail for such a "short" exposure time) and barely processed (no filtering or other, just histogram stretch). This suggests that with more time (and color) I may get a decent shot.

In This Issue . . .

Events for January

WAA January Lecture

"Chasing Shadows"
Friday January 13th, 7:30pm
Leinhard Lecture Hall,
Pace University, Pleasantville, NY

Our speaker will be Rick Bria. His presentation describes procedures, challenges and the rewards of timing asteroids occulting distant stars.

Rick has been an amateur astronomer and astrophotographer for over 40 years. He is a founding member of the Astronomical Society of Greenwich and has been a WAA member since the 1990s. Rick has contributed many of his excellent photos to the WAA Newsletter and he wrote the Almanac column for the Newsletter before Bob Kelly took it over. Rick is an Observatory Operator/Technician for the Stamford Observatory, Bowman Observatory, Mary Aloysia Hardey Observatory as well as several other private observatories. Directions and Map.

Upcoming Lectures

Pace University, Pleasantville, NY

On February 3rd, our presenter will be Brother Robert Novak.

Starway to Heaven

Ward Pound Ridge Reservation,
Cross River, NY

There will be no Starway to Heaven observing dates for January or February. Monthly observing sessions will recommence in March 2017.

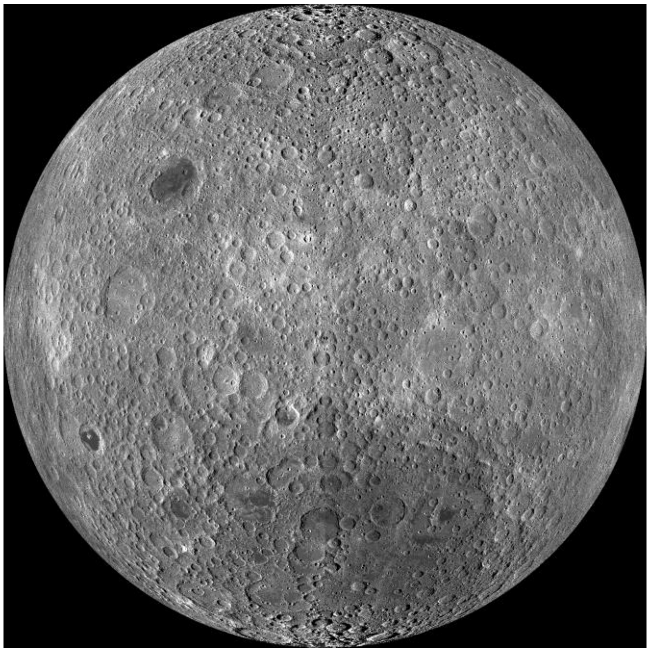
New Members. . .

Dr. Reshmi Mukherjee

Renewing Members. . .

John Higbee - Alexandria
Sharon and Steve Gould - White Plains
Robin Stuart - Valhalla
Mayan Moudgill - Chappaqua

Call: 1-877-456-5778 (toll free) for announcements, weather cancellations, or questions. Also, don't forget to visit the WAA website.



Tidally locked in synchronous rotation, the Moon always presents its familiar nearside to denizens of planet Earth. From lunar orbit, the Moon's farside can become familiar, though. In fact this sharp picture, a mosaic from the Lunar Reconnaissance Orbiter's wide angle camera, is centered on the lunar farside. Part of a global mosaic of over 15,000 images acquired between November 2009 and February 2011, the highest resolution version shows features at a scale of 100 meters per pixel. Surprisingly, the rough and battered surface of the farside looks very different from the nearside covered with smooth dark lunar maria. The likely explanation is that the farside crust is thicker, making it harder for molten material from the interior to flow to the surface and form the smooth maria.

Credit: APOD
Image Credit: NASA / GSFC / Arizona State Univ. / Lunar Reconnaissance Orbiter

Wanted Assistant Editor

The WAA newsletter (the *SkyWaatch*) is seeking an Assistant Editor. If you can help, please let us know. Your participation in editing, compositing and proofreading tasks or submitting articles or images, will be much appreciated. Email Tom at waa-newsletter@westchestersastronomers.org

ALMANAC
For January 2017 by Bob Kelly

Jan 5 Jan12 Jan 19 Jan 28

Mars sets just about 9:30 EST through April, serving as a benchmark for the evening sky. It's not the brightest of the planets, but with no first magnitude stars in that quadrant of the sky, its steady light stands out surprisingly well. Using our reddish fellow terrestrial planet as a bookmark, we can see the advance of the returning Sun and the beginning of Venus' fallback toward the solar glare.

First, Venus: The third brightest object in our skies, brightening toward its peak in February at magnitude minus 4.8(!), Venus starts its three-month-long fall toward to the solar glare from 47 degrees out from the Sun on the 11^{th}. It climbs higher on the ecliptic, so it still gains altitude in our evening twilight skies. Venus appears to fall short of meeting up with Mars, but the almost-meeting in our skies of the planets whose orbits bracket the Earth's is a pretty sight in late January and early February; and with a crescent Moon on 31^{st}, quite photo-worthy. Viewed with a telescope in daylight or bright twilight, Venus' phase shrinks past half-lit in January.

Neptune tries to photo-bomb two terrestrial planets at the start and middle of the month, but it'll be a challenging sight to see with Mars six magnitudes brighter on New Year's Eve and Venus 12 magnitudes brighter on the 12^{th}.

Orion, high in the south by 10pm, anchors the winter constellations that shimmer on clear, blustery winter nights. Faint Lepus nestles under the feet of Orion. (Of course, if I were a rabbit in the neighborhood of the big and little dogs, a bull and a hunter, I wouldn't want to attract much attention, either.)

The Quadrantid meteors sprinkle sparkles across the pre-dawn sky on the 4^{th}, a few hours before the strong, but short-lived, peak, with no competition from the Moon.

Jupiter rides high in the pre-dawn skies, at magnitude minus 2. It's a good month for following the Moon shadows, Moon shadows, Moon shadows (sounds like a song) on the planet.

Hey, it's dark until almost 6am! So see Jupiter as part of a nice triangle with the Moon and Spica on the 19^{th}. Watch the setting sun play on Luna's Apennine Mountains.

Mercury makes its vain leap into the morning sky; visible most of the month, rising at the start of morning twilight during the second full week of the month, but never getting very high in our skies. It makes a copy of the evening scene with Mercury falling seven degrees short of Saturn at their closest approach on the 9^{th}. Look low in the southeast. The 'other' bright object up and to the right is Antares marking the return of the scorpion out of the glare of the Sun. The morning planets provide good value for the early riser, if well-dressed against the cold. Look for a weather forecast of a clear patch after a warm frontal passage for watching the morning planets at a more tolerable temperature in a more stable sky.

Uranus, at just a tenth below magnitude plus 6, is well-positioned in the evening's southwest sky amid the faint fish of Pisces.

The Full Moon is not super this month, but very high in Gemini on the night of the $11\text{-}12^{th}$.

Favorable twilight passes of the International Space Station are in the morning sky through the 20^{th} and in the evening sky starting on the 27^{th}.

The Mars Rover Opportunity is in its 12^{th} earth year, over 4500 martian days, rolling around Endeavour crater. Curiosity is working in Gale Crater after 15km of driving over 1500 martian days, 5 earth years.

The year 2017 will be Cassini's last year in Saturnine orbit. After skimming outside the F ring twenty times, and between Saturn and its rings twenty-two times, a final pass by Titan will send the bus-sized explorer into Saturn's atmosphere.

Westchester Amateur Astronomers

We Visit the Meteorite Collection at Arizona State University

Larry Faltz

Following our April 2016 trip to Pasadena and visits to the Jet Propulsion Laboratory, Mt. Wilson Observatory and Mt. Palomar Observatory, we drove east on I-10 for six hours to reach the Phoenix area for a visit with my cousin Aryeh, a retired professor of linguistics at Arizona State University in Tempe. We planned to drop in on the meteorite collection at Arizona State University, which we first visited in 2011. Although the University of Arizona in Tucson is better known for astronomy programs, its academic and sports rival ASU is not far behind, particularly with regard to solar system research.

The ISTB4 at Arizona State University

It's not all that surprising that an Arizona university would be a leader in meteorite research or house a great collection. Meteor Crater, the "best preserved meteor crater on Earth," is located just over 3 hours north of Tempe, reached by interstates the entire way. Meteor Crater was the original home of the American Meteorite Museum, housing the collection of Harvey H. Nininger (1887-1986), a self-taught scientist who revived interest in meteorites in the 1930's and had the world's largest personal collection of objects from space. In 1958 he sold part of his collection to London's Natural History Museum, which already had a significant body of samples (now grown to over 2,000 individual meteorites in 5,000 pieces). This was the same year that Arizona State College became Arizona State University, with an expanded mission of scientific research and graduate education. Sensing an opportunity to carve out expertise in a field that would be essential to the imminent era of solar system exploration, ASU Coordinator of Research George A. Boyd and school president Grady Gammage obtained funds from the National Science Foundation to purchase the remainder of Nininger's collection. Thus the Arizona State University Center for Meteorite Studies (CMS) was born. Since its founding in 1960, it has become one of the world's leading centers for meteorite research and is the largest university-based space rock collection. You may recall that the Meteorite Men, Geoffrey Notkin and Steve Arnold, would often take their finds to CMS for analysis.

The 3rd floor atrium of ISTB4

The CMS collection includes meteors of every type and from every great strewn field. While most of them are housed in a vault near the research laboratories that is not accessible to the curious, a significant number of specimens have always been on display. When we visited in 2011, the museum was housed in a single room in an older school building, but in 2012 the university constructed a spectacular new home for its

School of Earth and Space Exploration (SESE). The Interdisciplinary Science and Technology Building IV (ISTB4) is a 293,000-square-foot facility that includes a large number of research laboratories and classrooms. It also was designed to facilitate ASU's interest in public outreach and pre-collegiate science. The lower floors include public displays, with a full-size model of the Mars Curiosity rover, video screens with information about space science (with a focus on lunar and Martian research, ASU specialties), a new meteorite museum and a high-definition theater. Laboratories are glass-enclosed to allow visitors to see the scientists at work (having been a research scientist at one point in my medical career, I can tell you that seeing scientists at work is not necessarily the most dramatic entertainment you can have). The third floor is a huge atrium extending to the roof. Its "Crater Carpet" is a matrix of carpet tiles with images of all the large craters in the Solar System.

The Crater Carpet

After parking our car in a very large on-campus parking structure, we went next door to ISTB4. The Curiosity model was displayed at the entrance, easily visible from the street. Inside, recent images from the real Curiosity were being shown on a large plasma screen, as were some deep space images on another monitor. Unfortunately, there wasn't a public event in the theater on a date we could attend, but we stuck our heads in anyway and found an undergraduate lecture on global warming in progress. At the information desk, we ran into Meg Hufford, who is the senior coordinator of SESE. We explained who we were, and she was most hospitable and enthusiastic. She tried to find Dr. Meenakshi Wadhwa, the Director of the CMS, but alas Dr. Wadhwa was in a meeting, the curse of department directors and administrators everywhere. Ms. Hufford explained to us that ASU currently has instruments on 8 NASA missions, and is the principal operator of the Lunar Reconnaissance Orbiter Camera (LROC). ASU was picked to design, oversee and operate Mastcam-Z, the main color panoramic stereo imager on the new Mars 2020 rover, a new version of Curiosity with improved instrumentation, which is why the rover model was so prominently displayed.

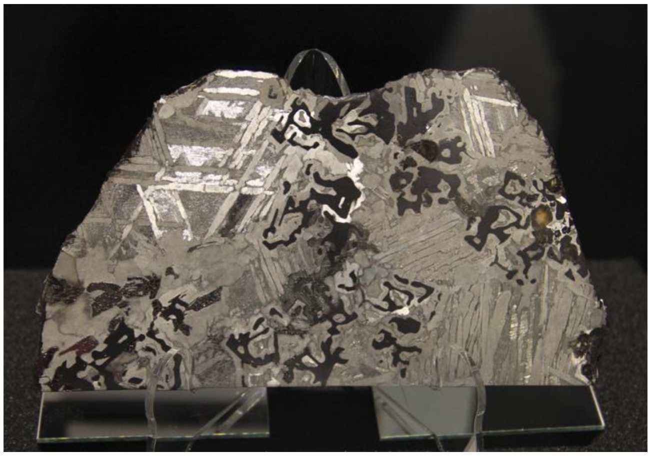
In the first floor corridor, a 300-pound specimen of the Canyon Diablo meteorite, the body that created Meteor Crater, was on display, perhaps as an enticement to get visitors to go up to the second floor museum. Other space science displays included a 10-foot high model of a Saturn V.

This 300 lb. piece of Canyon Diablo, originally owned by Harvey Nininger, is displayed near the entrance to ISTB4. (The meteor is on the left!)

The meteorite museum occupies a large part of the ISTB4's second floor lobby. Modern vitrines house a substantial number of specimens, both cut and uncut. There are posters explaining meteorite science, solar system history and the story of the collection.

Part of the Meteorite Museum at ASU

We spent over an hour and a half looking at the collection. There were specimens from every famous source, with names familiar to even the most casual meteorite enthusiast: Gibeon, Canyon Diablo, NWA, Seymchan, Sikhote-Alin, Murchison, Allende. There was a small piece of Black Beauty, the famous Martian meteorite, and a large sectioned piece of the Willamette meteorite that is the centerpiece at the Rose Center in New York.



A 381-gram slice of Seymchan, a pallasite found in Russia in 1967, about 7" across

Another view of the museum

Once the Meteorite Men show became popular, the public descended on CMS, sending or bringing putative meteorites for evaluation, most of which were not actual meteorites. Overwhelmed, the Center's analytical service had to close to public in 2010, and it refers the curious to local natural history museums or state geology offices. The [Robert A. Pritzker Center for Meteorics] and Polar Studies at the Field Museum in Chicago still has a public identification service.

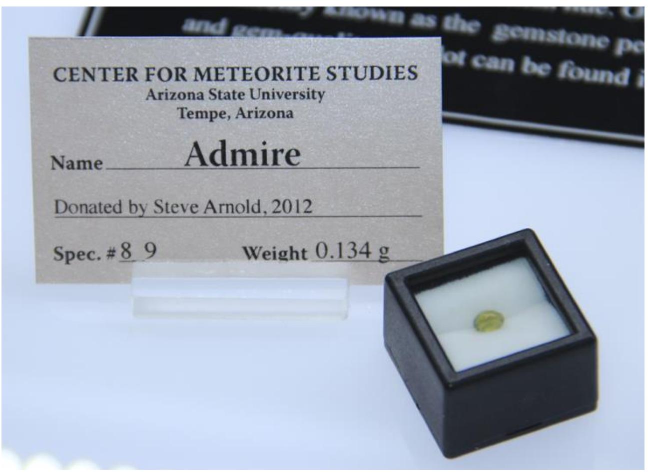
Here are just a few of the many specimens on display:

Clockwise from top left: (1) Cut section of Allende, a chondrite, about 4½" across. ASU holds 41 kg of Allende meteorites; (2) NWA 7611, a lunar achondrite, 311 gm; (3) Orange River, medium octahedrite iron meteorite, 2050 gm; (4) Ainsworth Central Missouri (actually found in Nebraska) Iron meteorite, 995 gm

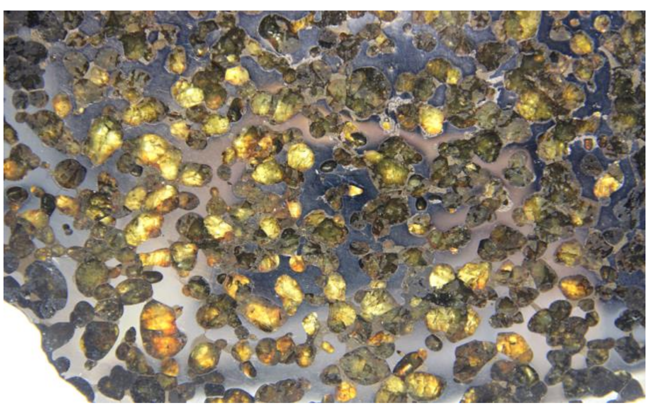
Section of chondrite NWA 6991, about 2" across, 39.4 gm

NWA 1929, Padvarninkai, an achondrite thought to come from asteroid 4 Vesta

Tissint: Martian shergottite fragments, from a total of 378.2 grams in the collection



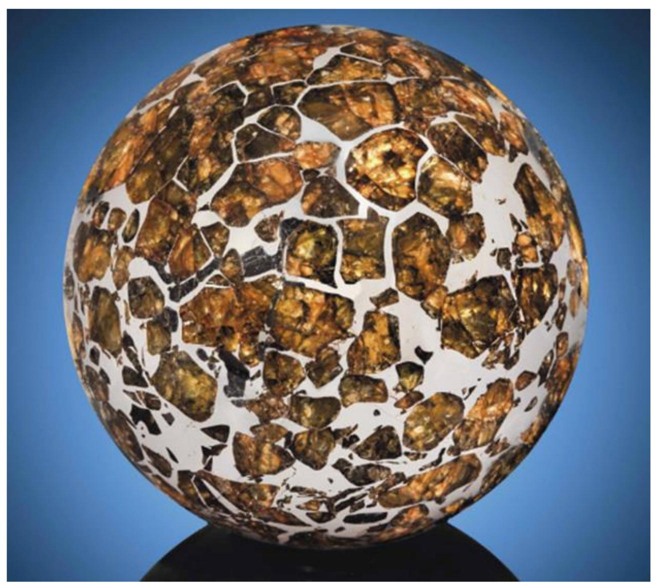
One of several polished peridots from pallasite meteors donated by Meteorite Man Steve Arnold.



A cut and polished section of a pallasite, showing olivine inclusions. The pinkish and dark coloration in the center is a reflection of the camera and my head.

The museum was full of wonderful factual information. For example, a note in the case of NWA 7611, a lunar regolith breccia, informs us that "of the 49,579 classified meteorites world-wide (as of August 19, 2014), 183 are lunar, or 1 in 267." But to be more accurate, "a better estimate is provided by the statistics of meteorites collected from Antarctica, since all meteorites collected from this continent are classified… [Of the] 40,204 classified meteorites from Antarctica, 34 are lunar, or 1 in 1182, only 0.09% of finds." Another note in this display tells us that "rocks exposed to cosmic rays (in space or on planets without an atmosphere like the Moon's surface) acquire levels of certain isotopes above that found in rocks on the Earth. Many of these isotopes are radioactive, so their abundances can be used to date how long the rock was exposed on the Moon's surface, how long it took to travel to Earth, and how long ago it fell."

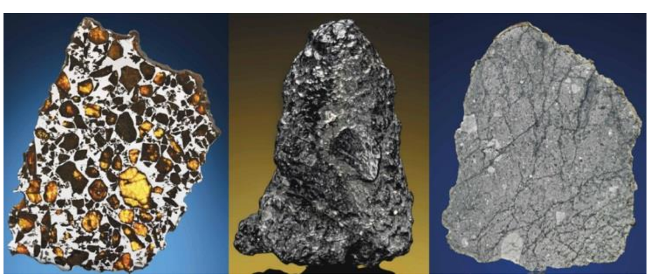
Many of us own a few meteorite specimens, and some WAA members have impressive collections. Al Witzgall, who's given several terrific lectures to WAA over the past few years, is a serious collector and meteorite expert. He was extraordinarily generous when at one recent club meeting he brought a small piece of the Park Forest chondrite meteor (a 2003 impact) as a gift for Elyse, who grew up in that suburban Chicago town.



Machined Seymchan pallasite, 2" diameter, 434 gm

Meteorite collecting can be a serious business. Important meteorites, especially large ones, fetch astonishing prices. The very same day that we were at ASU, half a world away Christie's auction house in South Kensington, London, held a meteorite auction. The expectations for this sale were rather dramatic, reflecting the hot market for important meteorites. Some of the sellers were perhaps overly greedy, but on the whole most of the lots sold for higher than their estimates. The largest piece in the catalogue, a 1,430 pound iron meteorite containing “extraterrestrial gemstones” (presumably a pallasite), had a reserve of $1.1 million but didn’t sell. Neither did a large chunk of the Chelyabinsk meteor that was expected to fetch at least $426,000, although a group of 85 small fragments of Chelyabinsk, weighing a total of 300 grams, sold for $1,346. The hit of the show was a Seymchan pallasite machined into a 2-inch diameter sphere, which was bid up to $135,000, nine times the expected price.

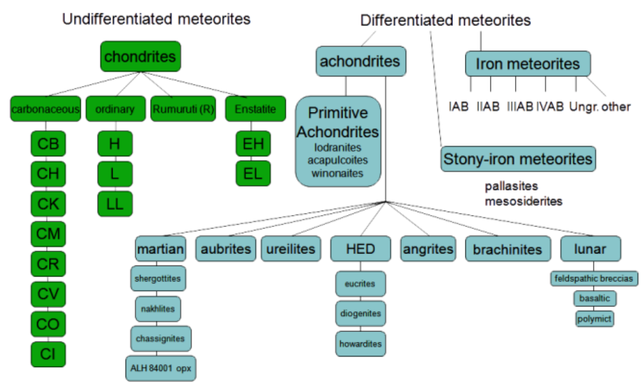
A successful bidder acquired a tiny piece of NWA 7034, nicknamed Black Beauty, for $62,213. This meteorite was found in 2011. Its several pieces weighed a total of 320 grams. It was purchased from a Moroccan dealer by Jay Piatek, a physician who made a fortune as a diet doctor in Indianapolis. He became fascinated by meteorites and in a fairly short period of time built an enormous collection in the very active and sometimes shady international meteorite market. He donated a slice of Black Beauty to the University of New Mexico, another academic institution with a strong meteorite collection and research program. They determined that it was Martian in origin, but further analysis showed that the meteorite didn’t fit into any of the previously known Martian types. It was called a “basaltic breccia.” It had the highest water content of any Martian space rock and therefore was thought to have originated during volcanic activity in the “Amazonian” epoch in Mars when oceans were still present on the red planet. The piece of Black Beauty that ASU acquired in a trade with Piatek weighs 19 grams. Piatek’s obsession with Black Beauty, and the importance of the specimen (now amplified by the recent evidence of early Martian oceans) was the subject of an interesting profile in *Science* in 2014.



Three more lots from the Christie’s sale: (L) a 5” x 3” x 1/8” slice of NWA 10023, a pallasite ($6,821). (C) Black Beauty, NWA 7034, a Martian meteorite. It looks big, but it’s only big in price ($62,213, 31 gm, 1 3/4” x 1½” x 2/3”). (R) NWA 8022, a 4½” x 4” x 1/8” 43 gm slice of a lunar meteorite ($13,463)

Meteorites are named for the locations where they are found. The exact site of most of the specimens found in the Sahara isn’t usually known, so they are referred to as “NWA” for “Northwest Africa,” primarily Morocco and Western Sahara.

The taxonomy of meteorites is still somewhat unsettled, with alternative schemes occasionally challenging the generally accepted format that NASA distributes. The division into differentiated and undifferentiated structures is a good way to start. The undifferentiated meteorites are chondrites. They were never part of a body large enough to have a core and surrounding mantle. These are the oldest rocks in the solar system. They contain chondrules, millimeter sized silicate mineral aggregates that are thought to have formed in space during the time that the solar nebula was condensing, and then were aggregated into small asteroids. About 82% of all meteorite falls are chondrites. Among the chondrite subgroups, the relatively rare carbonaceous chondrites contain the highest content of water and organic compounds. This is taken to be evidence that they never underwent the heating involved in planetary formation and are therefore the true earliest representatives of the proto-solar nebula.



NASA’s schema for meteorites

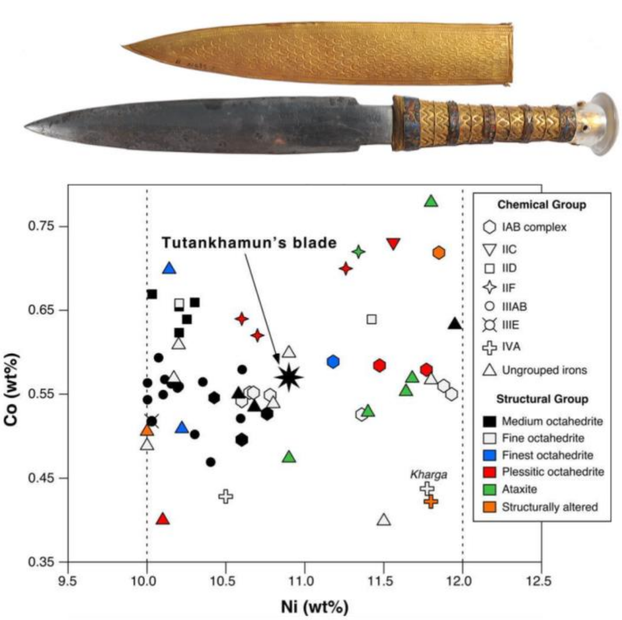
The other types of meteorites are considered differentiated because of their origin. Achondrites, about 8% of falls, are stony meteorites that lack chondrules. They originate from the mantle of larger bodies in the solar system that have a distinct core and crust, such as asteroids, planets, or moons. They are the detritus of collisions with other large bodies. These impacts release molten fragments that re-form in the coldness of space.

Iron meteorites, 4.8% of all falls, come from the cores of the earliest planetesmals that were large enough (>1 km) to condense gravitationally but then were disrupted by collisions in the chaotic early solar system. They contain two iron-nickel alloys, kamacite and taenite, in various proportions. The alloys were once molten, solidifying as they cooled over thousands of years. If the nickel content is not too high or too low, the cooling alloy crystallizes into the famous Widmanstätten pattern. This crystalline matrix cannot form on Earth. It is brought out by etching a cut and polished section of an iron meteorite with either nitric acid or ferric chloride.

My Gibeon meteorite, showing the Widmanstätten pattern. 5½" x 1¼" x 1", 700 gm

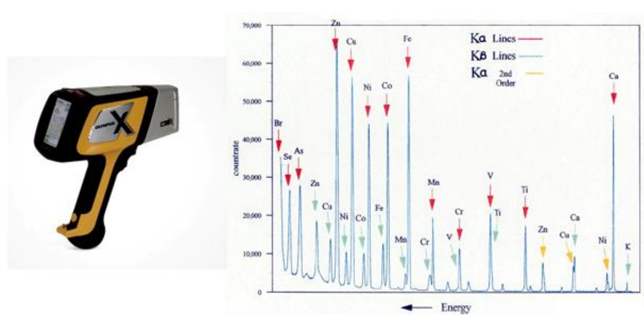
The stony-iron meteorites are the third differentiated group, representing just 1.2% of meteorites. They arise from the core-mantle boundary of a broken up planetesmal. There are two types, pallasites and mesosiderites. Pallasites generally contain olivine, the magnesium iron silicate mineral that is known as peridot in its terrestrial gemstone form. They are the most beautiful of the space rocks when cut in section (or formed into a $135,000 ball) and back-lit. Mesosiderites are the rarest meteorites (outside of Martian and lunar specimens) with only 208 falls being identified. Some of these falls, however, deposited large masses of pallasites. The Vaca Muerta fall in the Atacama Desert has so far yielded nearly 4 tons of material.

I reviewed the history of meteorites in an article in the June 2013 SkyWAAtch. Before they became treasured scientific and collectable objects, meteorites were used for tools, especially in metal-poor cultures. Ancient civilizations, from the Neolithic period forward, knew that on rare occasions metal chunks fell from the sky and could be worked into useful objects. The Egyptian word for iron was "metal from heaven." In an article[1] published in June 2016 in *Meteoritics & Planetary Science*, a group from several Italian research universities used the technique of X-ray fluorescence spectroscopy to study the blade of a sword found in King Tutankhamun's tomb that dates from about 1400 BCE. There had been speculation from the time it was found in 1925 by the celebrated Howard Carter that it was of extraterrestrial origin, but this study was the first to conclusively prove that the metal was meteoritic.



King Tut's sword and the data showing that its nickel-cobalt ratio is similar to other iron meteorites

X-ray fluorescence spectroscopy is a method of non-destructive chemical analysis. X-rays with enough energy can ionize an atom by ejecting one of the inner electrons. An electron from an outer shell drops into the vacant orbital and in so doing emits another photon with a characteristic energy. Since the energy levels of electron orbitals for all atoms are well known, the detection of this "fluorescent" photon and its intensity gives the identification and quantification of the emitting atom. The process can even be combined with microscopy to give elemental maps of a surface. Although the technique usually requires the sample to be held in a vacuum, inside devices that are table-top in size, there are hand-held versions for field use. These are particularly useful in the mining industry, but meteorite hunters also use them.



Hand-held X-ray fluorescence analyzer (Olympus) and a typical spectrum of elemental abundances

Today, jewelers and craftsmen still make useful objects from meteorites (the annual Tucson Gem and Mineral Show is an important destination for meteor-

[1] Comelli, D, D'Orazio, M, Folco, L, et. al., The meteoritic origin of Tutankhamun's iron dagger blade, *Meteoritics & Planetary Science* 2016: 1-9, reported in the NY Times on June 2, 2016.

ite collectors and dealers) but they recognize the importance of highlighting the object's natural structure. With this in mind, some extraordinary works of art have been created.

Letter opener from a Gibeon meteorite, made by jeweler Dan Telleen, Vail, Colorado

As we were walking around the ASU museum, we noticed some students assembling in a classroom on the same floor. I stuck my head in to see what was going on, and one of the faculty members came over to ask if he could help me. After giving my *bona fides* as an amateur astronomer and president of WAA who was vising the CMS, Elyse and I were invited in to the senior thesis defense of ASU student Michael Busch, who was about to graduate with a dual bachelor's degree in astrophysics and physics. Busch was recently awarded a National Science Foundation graduate fellowship and is now doing graduate work at Johns Hopkins. He was also a recipient of the inaugural ASU Origins Project Undergraduate Research Scholarship.

Michael Busch

Busch's research advisor was Judd Bowman, an Associate Professor at the School of Earth and Space Exploration and a member of the Low Frequency Cosmology Group at ASU. The project was about as far away from meteorites as one can get. It concerned the earliest epoch of reionization, when neutral hydrogen was ionized by ultraviolet light from the first stars and galaxies in the universe at high red shifts. Busch's thesis was officially entitled "Enabling a New Window on the Earliest Astrophysical Structures from the Dark Ages, First Light, and Reionization." Busch was interested in detecting signals from reionization in the 21-cm neutral hydrogen line. Reionization might be seen as "holes" in the 21-cm background. There are at least two major problems in acquiring the data: foreground galactic sources tend to drown out the signal, and cosmological expansion red-shifts the signal from its native 1,420 Mhz to 140-200 MHz, a frequency range that has lots of interference from terrestrial sources. Busch analyzed signals from the Very Large Array in New Mexico with sophisticated computer software to model solutions that could be applied to data from the Murchison Widefield Array (MWA) in Australia. The MWA, in which ASU is a major partner, has as one of its major objectives the detection of these low-frequency signals from the epoch of reionization. With a combination of humor and scientific precision, and fully at ease in front of an audience of faculty, students and even his dorm-mates, Busch related the many issues that he confronted trying to extract useful results from the VLA signals, an effort that occupied him for the better part of a year. It was a wonderful experience to hear a bright, persevering student who had such a clear command of his area of study.

A couple of weeks after I returned to New York, I was intrigued to come upon one of the latest papers from the Planck Collaboration, "Planck 2016 intermediate results. XLVII. Planck constraints on reionization history," submitted to Astronomy & Astrophysics and posted on arXiv:1605.03507. The paper has almost 200 authors, one of whom is Charles Lawrence, with whom we went to Palomar and who spoke about Planck at the October 2015 WAA meeting. Using sophisticated techniques and a lot of computer power and human brain power, these astronomers were able to determine from the cosmic microwave background signal that "the Universe is ionized at less than the 10% level at redshifts above $z \approx 10$. This suggests that an early onset of reionization is strongly disfavored by the Planck data." A red shift of 10 equates to 466 million years after the Big Bang, based on the most recent values from Planck of the universe's matter and energy densities, flatness and the Hubble constant. It will be interesting to see if eventually the Murchison Array can capture the red-shifted 21 cm signal from the era of reionization and either corroborate or challenge the Planck findings.

Our astronomical experience at ASU did not end here. Meg Hufford enthusiastically directed us to the Interdisciplinary A-Wing building, which houses the operations center for the Lunar Reconnaissance Orbiter Camera, and I'll write about that next month. ■

Big Science in Small Packages

Marcus Woo

About 250 miles overhead, a satellite the size of a loaf of bread flies in orbit. It's one of hundreds of so-called CubeSats—spacecraft that come in relatively inexpensive and compact packages—that have launched over the years. So far, most CubeSats have been commercial satellites, student projects, or technology demonstrations. But this one, dubbed MinXSS ("minks") is NASA's first CubeSat with a bona fide science mission.

Launched in December 2015, MinXSS has been observing the sun in X-rays with unprecedented detail. Its goal is to better understand the physics behind phenomena like solar flares – eruptions on the sun that produce dramatic bursts of energy and radiation.

Much of the newly-released radiation from solar flares is concentrated in X-rays, and, in particular, the lower energy range called soft X-rays. But other spacecraft don't have the capability to measure this part of the sun's spectrum at high resolution—which is where MinXSS, short for Miniature Solar X-ray Spectrometer, comes in.

Using MinXSS to monitor how the soft X-ray spectrum changes over time, scientists can track changes in the composition in the sun's corona, the hot outermost layer of the sun. While the sun's visible surface, the photosphere, is about 6000 Kelvin (10,000 degrees Fahrenheit), areas of the corona reach tens of millions of degrees during a solar flare. But even without a flare, the corona smolders at a million degrees—and no one knows why.

One possibility is that many small nanoflares constantly heat the corona. Or, the heat may come from certain kinds of waves that propagate through the solar plasma. By looking at how the corona's composition changes, researchers can determine which mechanism is more important, says Tom Woods, a solar scientist at the University of Colorado at Boulder and principal investigator of MinXSS: "It's helping address this very long-term problem that's been around for 50 years: how is the corona heated to be so hot."

The $1 million original mission has been gathering observations since June.

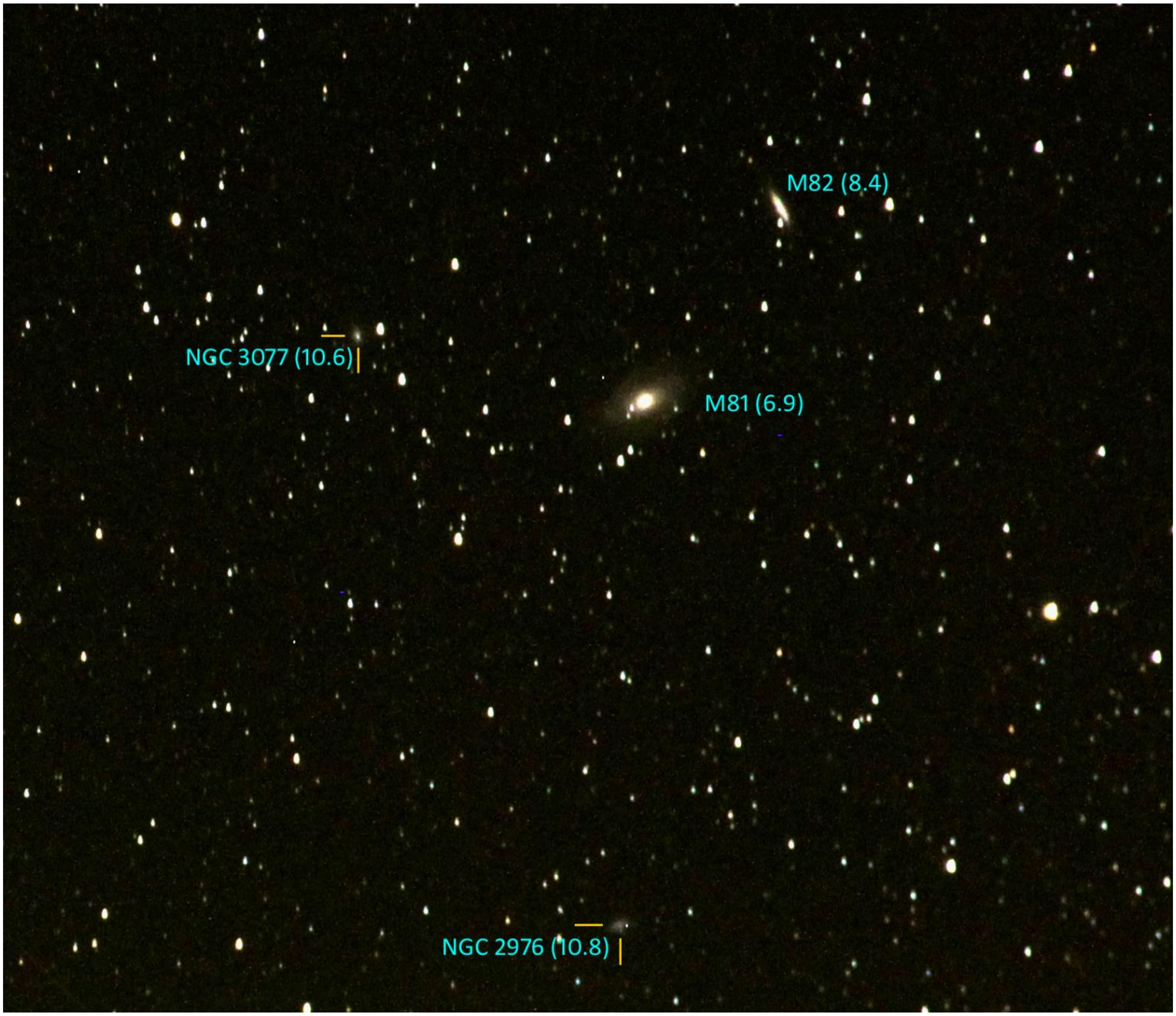
The satellite will likely burn up in Earth's atmosphere in March. But the researchers have built a second one slated for launch in 2017. MinXSS-2 will watch long-term solar activity—related to the sun's 11-year sunspot cycle—and how variability in the soft X-ray spectrum affects space weather, which can be a hazard for satellites. So the little-mission-that-could will continue—this time, flying at a higher, polar orbit for about five years.

If you'd like to teach kids about where the sun's energy comes from, please visit the NASA Space Place: http://spaceplace.nasa.gov/sun-heat/

This article is provided by NASA Space Place. With articles, activities, crafts, games, and lesson plans, NASA Space Place encourages everyone to get excited about science and technology. Visit spaceplace.nasa.gov to explore space and Earth science!

Astronaut Tim Peake on board the International Space Station captured this image of a CubeSat deployment on May 16, 2016. The bottom-most CubeSat is the NASA-funded MinXSS CubeSat, which observes soft X-rays from the sun—such X-rays can disturb the ionosphere and thereby hamper radio and GPS signals. (The second CubeSat is CADRE — short for CubeSat investigating Atmospheric Density Response to Extreme driving - built by the University of Michigan and funded by the National Science Foundation.) Credit: ESA/NAS

Galaxies of the M81 Group



DSLR view of galaxies M81 (Bodes's Nebula) and M82 (Cigar Galaxy) with surrounding star field.Taken at Camp Hale, Colorado (9,235 feet, SQM 21.71) on July 6, 2016. Canon T3i mounted on iOptron SkyTracker, 18-135mm zoom lens (effective focal length 216 mm on the camera's APS-C sensor), f/5.6, 180 seconds at ISO 1600. Cropped and contrast-adjusted in Photoshop. Taken by Larry Faltz.

In addition to the famous M81 and M82, two other bright galaxies in the M81 Group are also seen. These galaxies are posed for excellent viewing in the evening from late winter through the early summer.

Galaxy	Type	Distance (MLy)	Magnitude	Discovered
M81	Spiral	12.0	6.9	1774 (Bode)
M82	Irregular, starburst	12.0	8.4	1774 (Bode)
NGC 2976	Spiral (unbarred)	11.6	10.8	1801 (W. Herschel)
NGC 3077	Irregular	12.8	10.6	1801 (W. Herschel)