EYEPIECE

Journal of the Amateur Astronomers Association of New York
October 2009
Volume 57 Number 10, ISSN 0146-7662

What to Consider If We're to Live Off the Land in Space

By Greg Matloff

Most astronomers, amateur and professional alike, have occasionally wondered how human civilization might ultimately expand beyond the confines of the Earth. A few years ago, I was fortunate enough to be part of a collaborative effort investigating this question.

From 1999 to 2007, I consulted for Les Johnson's group at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Ala., on various aspects of in-space propulsion, notably the solar sail. For part of that period, my artist wife C Bangs was also supported by NASA Marshall to visualize various aspects of in-space propulsion.

In summer 2003, Les was asked to participate in a NASA workshop considering how current space-technology development efforts could contribute to the evolution of an off-planet civilization. Many team members, including me, participated in preparing the presentation. This work was ultimately incorporated in a NASA report, a paper in the *Journal of the British Interplanetary Society* and an article in *Analog*. Finally, Les, C and I realized there was a book in this.

Of course, many others have previously considered how we might ultimately settle the space frontier. Most notable, perhaps, is the contribution of Princeton physics professor Gerard K. O'Neill and his collaborators in the 1970s. We realized our major contribution would be to show how we could get from here to there.

The final product, Matloff, Johnson, Bangs, "Living Off the Land in Space," was published in 2007. Les and I split the writing. C created chapter frontispiece art.

To ground our work in reality, we reviewed the record of terrestrial migrations and expansions. These included ancient Greek colonies in southern Italy, Asia Minor and the coast of the Black Sea. More recent attempts at territorial expansion include the unsuccessful Viking New-World colony, successful colonies in the Americas established by European powers and the expansion of the young USA into the western frontier.

A number of characteristics distinguish successful historical migrations from failures. For example, migrants had to learn to live off the land--to make use of in situ resources. In many cases, such as the settlement of the Old West, it was helpful to have collaboration between government and the private sector.

In space, therefore, we should choose technologies carefully. If we settle the Moon, for example, nuclear-fission reactors might appear at first glance to be an ideal energy source. But, although nuclear would alleviate the issue of energy production during long lunar nights, it's hard to see how a choice of nuclear over solar could ever lead to lunar independence from Earth.

In-space propulsion technologies could contribute to space-settlement efforts. For instance, the solar-photon sail--pushed through space by linear-momentum transfer from reflected solar photons--could carry water mined on comets or hydrated asteroids towards human habitats in dry solar systems. Such sails could also direct concentrated sunlight beams against certain classes of near-Earth asteroids, raising a high-velocity jet of evaporated asteroid regolith to alter the asteroid's solar trajectory.

The solar-thermal rocket, another technology investigated by Les' team, would operate by concentrating sunlight to heat and exhaust hydrogen propellant. The concentrator optics of this device could also be used to

Matloff continued on page 10

What's Up

By Tony Hoffman
The Sky for October 2009

October's Constellations. Arcturus lies low in the west-northwest after sunset and is all but lost in the twilight by Halloween. The Big Dipper swings low into the northwest. The Summer Triangle stands nearly overhead, while Hercules and Corona Borealis start their swing into the west. The plane of the Milky Way bisects the sky from northeast to southwest, with Cygnus at the zenith and Sagittarius and Scorpius (with Ophiuchus and Scutum above them) low in the southwest. Capricornus lies near the meridian in the early evening, holding Jupiter as well as Neptune. Uranus lies near the Aquarius-Pisces border. Cepheus, Cassiopeia and Perseus climb in the northeast, while Pegasus swings up in the east, followed by Andromeda, Triangulum and Aries. Aldebaran rises in the early evening, followed by the Pleiades. Auriga *(see below)* climbs into the northeast in the early evening.

The Long Eclipse of Epsilon Aurigae. Next to Capella, the brightest star in Aurigae, the Charioteer, lies a trio of third-magnitude stars collectively known as the kids, as in baby goats. (In old star maps, Auriga was sometimes depicted as a shepherd, with one goat, Capella, slung over his shoulder and the three kids in hand.) The nearest kid to Capella is Epsilon Auriga, an eclipsing binary, and a most unusual one. Normally at magnitude 3, it dims by close to a magnitude every 27 years, in an eclipse that lasts fully two years, brightening slightly at the middle of the eclipse. The primary star is a white supergiant, but what causes such a long eclipse? A popular theory is that it's a solar system in process of formation, a dusty protoplanetary disk with a gap in the center. You can help solve this mystery. As part of IYA 2009, the Citizen Sky project (www.citizensky.org) is enlisting volunteers to make magnitude estimates of this star. The earliest stages of the eclipse have begun, so now's the time to get involved.

October 4 Full Moon at 2:10 a.m.
October 6 Mars lies near Pollux; Mercury at greatest elongation in morning sky.
October 8 Mercury lies 0.3 degrees from Saturn.
October 11 Last-quarter Moon at 4:56 a.m.; Moon lies near Mars.
October 13 Moon at perigee, 229,327 miles from Earth, 8:24 a.m.; Venus lies near Saturn.
October 16 Moon lies near Saturn and Venus.
October 18 New Moon at 1:33 a.m.
October 21 Orionid meteor shower peaks; Moon lies near Antares.
October 27 Moon lies near Jupiter.

Sun Returns to Quiescence

By Joseph A. Fedrick

I last observed spots on the Sun July 8. A fairly large group of spots was rotating off the earthward-facing side of the solar disk. After that date, I saw no more spots. I projected the image of the Sun's disk using my 60mm refractor on August 6, 16, 30, September 6 and 13, and saw no spots on the image of the solar disk. Only a blank, empty disk stared back at me. So the sunspot minimum continues, with only the occasional appearance of noticeable spots on the solar disk. It continues to appear that the new sunspot cycle will peak late and perhaps be less intense that the previous cycle. ■

Article Highlights New Type Of Astronomy 'Clubs': Online

Amateur astronomers "are beginning to look very different from what they did only a few years ago," an article in last month's *Sky & Telescope* observed. "Progressive clubs are incorporating new media into their offering, and individuals are finding more ways to make their hobby accessible 24 hours a day," whether from developing an iPhone app, building a social-networking site, Twittering local sky and observing information or attending a virtual-world meeting.

Author Laura K. Kinoshita, noting that many amateurs get most of their info online, said links among people who enjoy astronomy are becoming increasingly common, "evidence that the way people engage with astronomy is changing in irreversible ways.

"Even the act of 'stargazing' no longer requires a telescope, access to dark skies, or the ability to go outdoors," Kinoshita noted. "Internet access to telescopes and digi-

Sky&Tel continued on page 4

A Message from AAA President Richard Rosenberg

Hello, members:

The AAA's descriptive-astronomy class will be held on six consecutive Wednesday evenings at 6:30 on the second floor of our headquarters at 120 Warren St. Each session will last two hours. The first session will be on October 21. The instructor is AAA board member Shana Tribiano, associate professor of physics at Borough of Manhattan Community College. The fee is $45 for members and $70 for non-members. To enroll, show up with a check made out to the Amateur Astronomers Association. Members who have already taken the class can attend at no cost. We'll also give a class in physical astronomy this spring.

Our 2009-2010 lecture series at the Kaufmann Theater of the American Museum of Natural History begins on Friday, October 2. Michael Way of NASA's Goddard Institute for Space Studies and Ames Research Institute will speak on "100 Years of Cosmology." We begin at 6:15 p. m.; enter on 77th Street.

The AMNH will host SciCafe on the first Wednesday of each month at the Gottesman Hall of Planet Earth. Admission is free. At the inaugural event at 7 p. m. October 7, Ben Oppenheimer of the museum will discuss exoplanets and the search for life. There will be a cash bar; you must be at least 21 to attend.

Once again, we'll be at Pier 84 on the Hudson River at West 43rd Street on Sunday afternoon, October 4 to celebrate the autumn equinox. Rik Davis will bring his scope and solar filter. I'll give a short talk at 5:45 and we'll hang around after sunset to view Jupiter. Come join us!

Observing at Manhattan's rejuvenated High Line has been a terrific success. We'll continue it every Tuesday in October near the entrance at 14th Street and 10th Avenue.

Saturn has returned to the morning sky and has very close conjunctions with Mercury October 8 and Venus October 13. Jupiter is still prominent in the evening. We'll have a final dark-sky observing session at North-South Lake October 10.

Rich Rosenberg, AAA President, president @aaa.org, (718) 522-5014

'100 Years of Cosmology' Kicks Off AAA Lectures Oct. 2

Michael Way, astronomer/computer scientist at NASA's Ames Research Center and its Goddard Institute of Space Studies, will give the first lecture of the AAA's 2009-10 lecture series Friday, October 2, on "100 Years of Cosmology: From Spiral Nebulae to the Cosmic Microwave Background." The free public lecture is at 6:15 at the AMNH's Kaufmann Theater.

Discussing his talk, Way tells *Eyepiece*:

"I will start with the first redshift observations of spiral nebulae by Vesto Slipher and how people struggled to interpret them when astronomers believed the entire universe consisted of our Milky Way galaxy and nothing else. I will also discuss interpretations of solutions to Einstein's general-relativity equations in the context of developments in observational astronomy and cosmology. I will emphasize the importance of relatively unknown figures today, such as Friedman, Wirtz, Lundmark and Lemaitre and the fact that many people--including most astronomers--tend to give Hubble credit for discovering the expanding universe when Lemaitre should probably be given primary credit.

"I will then move on to the Big Bang and corresponding cosmic microwave background experimental detections and theoretical developments by people such as

Lectures continued on page 12

Lunar Landing, Space Priorities Discussed at AAA Seminar

By Mary Carlson

Chair, AAA Recent Advances Seminar

With NASA's Lunar Crater Observation and Sensing Satellite's (LCROSS) lunar impact imminent, the Recent Advances Seminar looked at the candidate shadowed craters. Depth and structure would be factors, as would be the crater's Sun mask (the depth of the crater below which the Sun doesn't penetrate) and its Earth Mask (the crater's depth not visible from Earth). NASA subsequently announced its selection: Cabeus A at the lunar South Pole region. On October 9, LCROSS will release its upper-stage Centaur rocket for impact. LCROSS will then fly through the plume, analyzing its content for water ice.

The Lunar Reconnaissance Orbiter (LRO), whose input contributed to the crater's selection, continues, through its seven instruments, to scout the lunar surface for safe landing sites, measuring and imaging the Moon's topography and temperature.

On the flip side, the subjects of NASA's budgets and priorities were hotly debated. A Presidential panel formed to examine feasibility and costs of future space exploration raised probing questions. With regard to the shuttle program due to be shut down next year, what's the long-term future of the International Space Station, slated for completion in 2010? Do we abandon it five years later and divert the money to manned flight? Do we have resources to land astronauts on the Moon in 2020 or even 2030? Do we bypass the Moon and concentrate on a manned Mars mission, or do we keep our astronauts in low-Earth orbit for the next few decades?

In the end, the panel recommended NASA abandon a rapid return to the Moon, instead concentrating on building a commercial space industry that would focus on such short-term objectives as supporting the ISS.

Meanwhile, the seminar looked briefly at the European Space Agency's Cosmic Vision 2015-2025 program and some possible mission candidates: Euclid (geometry of the universe), Cross Scales (physical scales, shock waves and turbulence), IXO/XEUS (matter and energy through X-rays), Tandem (Titan and Enceladus), Solar Orbiter (Sun's atmosphere), LISA (gravitational waves), Marco Polo (near-Earth Objects), and Plato and Spica (formation of galaxies, stars, the solar system and planets).

Lastly, we looked at recent gravitational disturbances in Saturn's A Ring possibly caused by a nearby moon, and at the huge impact near Jupiter's South Pole.

Why not join us for dinner, the seminar and lively debate? October's seminar will be Thursday, October 15 at headquarters at 6:30 p. m. ■

Sky&Tel continued from page 2

tized surveys give people the ability to see stars online, rather than 3through the eyepiece. The popularity of astronomy and the ubiquitous nature of the web have given rise to a new meaning of the term 'armchair astronomy.' And amateur astronomers are spending increasing time online, using digital experiences to extend or enhance their time between real-life observing sessions."

Craig Nance, president of the West Hawaii Astronomy Club, terming the Internet the new king of amateur astronomy, is quoted as saying that "Instead of clubs with officers and structured administrations, everything just happens informally, and results are just as exciting."

Kinoshita cited the online forum at Galaxy Zoo (galaxyzoo.org), a virtual research project started by astronomers at the University of Oxford in England. "Volunteers sign up to classify more than 1 million galaxies, photographed in the Sloan Digital Sky Survey. More than 160,000 people have joined the effort to make more than 50 million classifications, including more than 2 ½ million classifications during last April's 100 Hours of Astronomy coordinated by the International Year of Astronomy 2009."

One participant, a Dutch teacher, made a discovery that enabled her to participate in a research campaign using Hubble. "It's amazing to think this object has been sitting in the data archives for years and that amateur volunteers can help by spotting things like this online." ■

The Hard Slog to Get to the Moon at Lower Cost

By Jason Kendall

On July 20 at the Hayden, Edward Belbruno, a celestial mechanic, described the rocky and tumultuous path of his life. The ostensible subject was low-energy paths to the Moon, but it became part memoir, part mathematical prestidigitation and strikingly emotional.

Belbruno described a career path that landed him in NASA/JPL in 1986, working on trajectories for Galileo, Cassini, Magellan and Ulysses. He noticed all trajectories for orbital transfer from Earth used the Hohmann transfer, a speedy trip with a figure-eight appearance, burning a lot of fuel to slow down at the destination.

Belbruno, author of "Fly Me to the Moon," knew chaos theory contained the possibility for low-energy orbital transfers. Digging around, he found a two-year-trip to the Moon without using rocket engines. Upon arrival at the Moon, it would be a chaotic, weakly tumbling orbit inside a "tube" of trajectories, tumbling around inside a tube rather than a smooth ellipse. Not something you want to force an astronaut to do, but a great way to get payload to the Moon at a fraction of the cost.

There are "weak-stability boundaries" (WSB) between Earth and the Moon, and even the Sun. Belbruno found you could launch a heavy rocket from an airplane and have it literally surf the edges of these boundaries, getting to its destination using no fuel. If the spacecraft is on one side of a WSB, it orbits one body, but if you pass through the boundary at a given point, you fall into orbit around the other body. Thus, a spacecraft could drift from Earth to the Moon, saving tens of millions of dollars of fuel per mission. Comparatively, the Apollo missions were extraordinarily expensive; with more than 75% of the vehicles' weight fuel, the cost was more than $100,000 per pound.

When Belbruno discovered these "ballistic-capture" routes to the Moon in 1986, he was met with great resistance by JPL engineers. In a workplace filled with engineers, anything having the name chaos in it didn't sit well. Even though his work was published by peer-reviewed journals, and backed up with rigorous computer simulations, he eventually had a falling out over it in 1990 and had to seek work elsewhere.

But then, fortune smiled on Belbruno. Japan's Hiten-Hagaromo lunar mission had a failure. The Hagaromo lunar orbiter was to drop a lander on the Moon and relay its signals back to the Hiten orbiter in low-Earth-orbit. But the Hagaromo craft's transmitter failed, and no signal from the lander could be obtained. Belbruno was approached by the Japanese Space Agency. It wanted Hiten to go to the Moon, but it only had 10% of the fuel required to use a standard Hohmann Transfer. In about a week, Belbruno calculated the trajectory, and Hiten arrived at the Moon in six months, as predicted. With extra fuel, the craft completed its mission and went to the L4 and L5 Lagrange points to look for dust particles trapped there using its one scientific instrument. This success ushered in an era of low-energy orbital transfers.

Belbruno has patented his trajectories, and ESA used them to get its SMART-1 mission to the Moon. NASA's GRAIL mission in 2011 will use his methods, and the STEREO missions are using these trajectories to advance the L4 and L5 missions, hunting for proto-planetary material possibly residing there. They hope to find the posited material for the great lunar impactor, Theia. Material could accumulate there and become too large to remain in that location. It would make a back-and-forth horseshoe-shaped orbit between the two L-points, until its chaotic, low-energy orbit intersected the young Earth. ■

Rosenberg on *NY Times* Blog

In August, I was asked by *The New York Times* to participate in its "Ask About" series, which appears on the paper's online City Room Blog and in truncated form in the paper. The topic, of course, was astronomy.

The Times solicits questions from its readership and I was to select five questions to answer each of three days. The questions covered all aspects of astronomy. The list of questions can be found on *The Times'* website at http://cityroom.blogs.nytimes.com/2009/08/24/ask-about-astronomy-in-new-york. The three sets of answers are at http://cityroom.blogs.nytimes.com/2009/08/26/answers-about-astronomy-in-new-york/, http://-cityroom.blogs.nytimes.com/2009/08/27/answers-about-astronomy-in-new-york-part-2/ and http://cityroom.blogs.nytimes.com/2009/08/28/answers-about-astronomy-in-new-york-part-3/.—*Richard Rosenberg*

Tech Writer Assesses Various Online Resources

In August, technology *columnist Don Reisinger informed* CNET.com *readers of a variety of online astronomy resources. Excerpts follow.*

Astronomy Network. Astronomy Network is a social network for astronomers. It sounds like a neat idea, but after you sign up, you quickly realize that the site has such a small community, it's tough to find value in it.

[However,] Astronomy Network's forums are a great place to hang out and communicate with some of the members. If you end up making friends with some users, you can instant message each other, send direct messages, upload videos and add images to the site. It's a full-featured social network designed specifically for amateur astronomers, but until more people join, it won't live up to its potential.

CalSky. CalSky is an invaluable astronomy tool. [It] provides you with a search that you can modify to find exactly what you're looking for tonight. Do you want to see the International Space Station? Are you looking for meteor streams? The site will help you find it all. When you get to the site, it determines your location. From there, it will find all objects you search for in the night sky on a specific day (you can search for any day of the year). The site explains each cosmic event and where to find it in the sky. When you click on an event, a page provides even more information.

EarthSky. EarthSky is an informative site for amateur astronomers. The main focus...is podcasts, which run daily, providing astronomers with news that could affect their stargazing. But EarthSky's real value is its daily "SkyWatching" feature, which provides tonight's sky conditions. Using that, you can find different visible constellations in the night sky.

Google Sky. Google Sky is a neat utility that helps you determine where celestial objects are before you run outside to check them out for yourself. The app lets you see constellations, planets, the solar system, an infrared view of the galaxy and more. It works far better in the browser than Microsoft's WorldWide Telescope. And since it provides you with the exact location of stars in the sky, it should help you find what you're looking for sooner.

Weather Underground. Weather Underground is a really useful site. Once you input your location, the service will show you a visual depiction of all the celestial objects visible from your location. When you click on one of the many objects displayed in the image, you'll be taken to a page detailing its important facts. So, if you're looking for its exact location, distance from Earth, and the peak times to see it, you should be happy.

World of Astronomy. If you're looking for an astronomy encyclopedia, the World of Astronomy is for you. Think of it as the Wikipedia of the astronomy world. When you search for topics in the World of Astronomy, you'll find some short definitions to simple topics. But where the encyclopedia shows off is in its listing of major constellations that you can see with your telescope. It features their exact location in the sky, so you can quickly find the constellation you're looking for.

WorldWide Telescope. Although it works best on the desktop, Microsoft's WorldWide Telescope has a great Web client that gives you the same view of the sky as the desktop version. You can choose to look through different constellations and also check out planets. If you want, you can enjoy a tour to see important stars and celestial objects that you don't want to miss. The online client works well, but beware it's much slower than the desktop app. In either case, WorldWide Telescope will help you learn before you head to the backyard. ■

NH Astronomy Meeting October 16-17

As chair of the New England section of The American Physical Society, the AAA's David Kraft has invited AAAers to attend the fall meeting at the University of New Hampshire, Durham, October 16-17. The theme: "Our Universe--400 Years After Galileo." Talks include "Professor Galileo's 21st Century Syllabus," "Fermi Gamma-ray Space Telescope: First-Year Highlights," "Imaging the Interstellar Wind and the Boundary of the Heliosphere in the 'Light' of Neutral Atoms using the Interstellar Boundary Explorer," "NASA's Kepler Mission: A Search for Habitable Planets" and "After 400 Years, Some of Us Still Get It Wrong: Science Errors on TV--A Personal Experience." Info: http://astrophysics.sr.unh.edu/nesaps. ■

Review: Pioneers on Whose Shoulders Astronomers Stand

By Edward J. Fox

It's said that the story is not necessarily in the destination. Sometimes, the journey is at least as interesting. That's certainly the case for "The Day We Found the Universe" by Marcia Bartusiak (Pantheon, $27.95).

On that day, January 1, 1925, Edwin Hubble formally announced the proof that some nebulae are, in fact, distant galaxies and that the universe consists of more than the Milky Way. That's the climax of the story. We know that eventual outcome, but the real story is how various pieces were developed over decades, by disparate players, and how the pieces finally came together.

Bartusiak weaves the back story over many years. As an excellent science writer, she explains various theories and equipment in clear, easily understood prose. She explains spiral and globular nebulae, those smudges of light that perplexed observers. Where are they? How far away? Are they spinning? Are they moving away or towards Earth? Are they blobs of gas within our galaxy or island universes outside the Milky Way?

She describes methods to measure relatively "small" distances--parsecs--using the parallax effect of observations from opposite sides of Earth's orbit, by measuring the angle from the two positions. She explains how this can't be used on very distant objects because there's so little difference on the apparent angle for them.

The author explains the importance of the development of photography to astronomy, and the newfound ability to check images of the sky for minute differences over time, and to identify objects and any noted motion as a result.

The importance of the development of the spectroscope and interferometers is stressed, as is how the shortening of light waves, as they approach, shifts the light to the blue and as an object recedes from the observer, to the red. "Blueshifts and redshifts are nothing less than the speedometers of the universe."

In addition, she lays out the humanity of the various players upon whose shoulders Hubble stood, in finally finding a way to prove what he and others had long suspected. She details the lives of the participants: their backgrounds, circumstances, health, egos and other complex human issues which played a part in the story. She does it with enough drama to keep the reader interested.

One of the most fascinating people Bartusiak spotlights is Henrietta Leavitt, in her role as one of the women Harvard "computers." These women were noted for their meticulous attention to detail, and skill with calculations. They were paid significantly less than a man would have commanded to perform this work.

Leavitt went well beyond being a "computer" and developed a system to facilitate measurement of distances to objects. This was done by using variations in periods of oscillation of brightness of a class of variable stars called Cepheids**.** This breakthrough provided a Rosetta stone to determining distances.

Unfortunately, Leavitt's boss at Harvard insisted she put that work aside to do other work he considered more important. She returned to her work years later. But when she was to be nominated by admiring Europeans for a Nobel Prize, they were informed she had passed away at 53. She was therefore ineligible for the prize.

Naturally, the story finally comes to Edwin Hubble. Bartusiak describes his background, education and how, as a Rhodes Scholar, he went to study in England. There he acquired the life-long mannerisms of an English gentleman. This, along with his movie-star good looks, gave him an attitude of superiority that put him at odds with many contemporaries. It made him very much a loner. But it was he who finally provided proof that there are galaxies outside our own.

Bartusiak's work is remarkable in the breadth of time and subject it covers in flowing prose, both relating an interesting story and cogently explaining scientific facts. It's meticulously documented.

This is a great read of the history of astronomy in the late 19th and early 20th centuries. It's notable in Bartusiak's description of the development of early versions of scientific tools we take for granted today. ■

Briefs: Major Discoveries of Water Made on Moon, Mars

The discovery of widespread but small amounts of water on the surface of the Moon was announced late last month. Three spacecraft picked up the signature of water, not just in frigid polar craters, where it has long been suspected to exist, but all over the lunar surface, previously thought to be dry. While the findings don't mean there are pools of liquid water sitting on the Moon, it means there is, unexpectedly, water potentially tied up or mixed in minerals that make up the lunar dirt. The new observations call into question 40 years of assumptions on the make-up of the lunar surface. The fingerprint of water was strongest at the poles. The signal varied in strength depending on time of day, with the most robust signals early in the morning and the lowest at midday.

Earlier, new data and images from NASA's new moon orbiter revealed tentative signs of water ice. Lunar Reconnaissance Orbiter (LRO) instruments have made measurements of space radiation in the lunar environment and have found more widespread possible signatures of water. First results indicate permanently shadowed and nearby regions may harbor water ice and hydrogen. One big finding: Hydrogen isn't confined to permanently shadowed craters. Among other tasks, the orbiter will hunt for water ice in the permanently shadowed craters of the south pole.

New data from the LRO suggest permanently shadowed craters at the Moon's south pole might be even colder than Pluto and other objects in the solar system's farthest reaches. LRO found craters along the south pole with areas permanently shielded from sunlight, and suspected to harbor deposits of water ice, have extremely cold temperatures. LRO has recorded minimum daytime brightness temps in portions of these craters of less than -397 degrees. The key point on temps isn't distance from the Sun, but the fact that there are regions at the poles of the Moon and Mercury that never see the Sun.

Craters gouged into the ruddy Martian terrain have revealed subsurface water ice closer to the equator than would be expected, new orbiter images show. The ice also seems to be 99% pure, instead of the dirty dust and ice mixture some scientists expected to see. While numerous surface features suggest water once flowed on Mars in the past, the discovery adds to evidence of recent years that water exists on present-day Mars in the form of subsurface ice. New observations indicate the presence of vast sheets of ice buried beneath the surface left over from when Mars' ice caps covered more of the planet. They ice averages a meter thick and contains about the same amount of frozen water as the Greenland ice sheet. This fresh evidence shows subsurface water ice extends further south than previously thought.

A series of huge cracks etched across crater basins on Mars were caused by lakes that have evaporated, a new study concludes. The cracks were initially thought to be a byproduct of thermal contractions in permafrost, but closer examination revealed they were too big for that explanation. Average diameter of the cracks is between 43-87 miles, with a width from 3 to 33 feet. It's estimated Mars was covered in significant amounts of water 3.8 billion-4.6 billion years ago. Lakes may have existed for several thousand years before drying out. The latest findings suggest in the northern hemisphere, some crater-floor cracks could have formed much more recently.

The most distant known galaxy to host a supermassive black hole has been discovered in a galaxy that formed in the early history of the universe. The galaxy, as large as the Milky Way, is about 12.8 billion light-years away. The black hole contains at least 1 billion times as much matter as our Sun. It's surprising that such a giant galaxy existed when the universe was only one-sixteenth its present age, and that it hosted a black hole so massive. The galaxy and black hole must have formed very rapidly.

NASA's Kepler telescope, which astronomers hope will find Earth-like planets, might also find habitable moons in other solar systems, new research suggests. A team has modeled properties of Kepler's instruments, simulating the expected signal strength a habitable moon would generate. An exomoon's gravity tugs on the planet it orbits, making the planet wobble while orbiting its star. Scientists found a Saturn-like planet, low in mass for its size, gives the best chance for detecting a moon. This is because planets like Saturn are large, blocking out much light as they pass in front of their star, but very light, meaning they will wobble much more than a heavy planet. If the Saturn-like planet is the right distance from its star, the temperature will allow liquid water to be stable on any sufficiently large moons around it. Such water

Continued on page 9

Briefs: Planet Whips Around Its Star in Less than a Day

Continued from page 8

-bearing moons might be habitable for life. The team found habitable exomoons down to 0.2 times the Earth's mass are readily detectable with Kepler. While it's not known if habitable exomoons are common in the galaxy, Kepler could potentially look for Earth-mass habitable moons around 25,000 stars up to 500 light-years from the Sun. In the whole sky, there should be millions of stars which could be surveyed for habitable exomoons.

A rare combination of three types of nebulas can be seen in a new image of the Trifid Nebula, a star factory 5,500 light-years away. The image provides a glimpse at early stages of a star's life. The heat and winds of newly ignited, volatile stars stir the Trifid's gas- and dust-filled cauldron. In time, dark tendrils of matter strewn throughout the area will collapse and form stars. The new image prominently displays the nebula's regions as seen in visible light. In the bluish patch to the upper left, a reflection nebula, gas scatters light from nearby Trifid-born stars. The largest of these stars shines most brightly in the hot, blue portion of the visible spectrum. In the round, pink-reddish area typical of an emission nebula, gas at the Trifid's core is heated by hundreds of young stars so it emits the red signature light of hydrogen, the major component of the gas. Gases and dust that crisscross the Trifid are the third kind of nebula in this cosmic cloud, known as dark nebulas because of their light-obscuring effects.

Mathematicians have proposed an alternative explanation for the accelerating expansion of the universe that doesn't rely on the idea of dark energy. According to the new proposition, the universe isn't accelerating, as observations suggest. Instead, an expanding wave flowing through space-time has caused distant galaxies to appear to be accelerating away from us. This wave, initiated after the Big Bang, could explain why objects today appear to be farther away from us than they should be according to the Standard Model of cosmology.

Small, sudden bursts of heat and energy, nanoflares, are responsible for the million-degree temperature of the Sun's atmosphere, a new study reveals. Why temperatures in the Sun's corona soar to several million degrees K., much hotter than temps nearer the surface, has long puzzled scientists. A theoretical model of the nanoflares, which are components of the loops of hot gas that arch high above the solar surface to make up the corona, was constructed. Nanoflares are so small they can't be resolved individually, so until now, no direct evidence of nanoflares was seen.

A newly discovered planet that whips around its star in less than a day may have been found mere cosmic moments before its demise. WASP-18b is only one of two known exoplanets that orbits its star in less than one Earth day, 0.94 days to be exact. Coupled with its huge mass, this leads to strong gravitational tugs between the planet and its star, WASP-18. These interactions create tides thought to squeeze and stretch the planet, and even alter its orbit. If the planet orbits faster than the star spins, the planet should be pulled toward the star; if the star spins faster, the planet should be pushed outward.

Perplexing blobs of gas in the faraway universe are a bit more comprehensible thanks to a new study. The massive blobs seem to surround very young galaxies. Various telescopes found their luminosity is likely due to energy released by black holes and star formation inside the galaxies. At a patch of space dubbed SSA22, 29 of these huge reservoirs of hydrogen gas can be seen. Blobs in this field date from when the universe was only about 2 billion years old. Point-like sources of bright X-ray light--signs of supermassive black holes--are within many blobs. Radiation from the black holes and star formation could be providing energy to light up the blobs.

Photons with a trillion times more energy than visible light are flying out of a relatively nearby galaxy. Until now, scientists didn't understand the light's origin, but a new study shows its source is a giant black hole inside M87. The radiation, in gamma rays, had been seen in 25 galaxies but its origin was unknown. Only in M87 could scientists narrow it down to the black-hole vicinity. Researchers were able to pin down the radiation's origination point by combining measurements of the gamma-rays with radio-wave observations.

Gas-giant planets that migrated in the early solar system could have violently knocked some asteroid-belt

Continued on page 10

Continued from page 9

denizens into their current orbits, according to a new study. This explains why asteroids in the outer part of the belt are different in composition from those in the inner part. Models haven't been able to reproduce the formation of Uranus and Neptune in their current orbits, so astronomers think they formed much closer to Jupiter and Saturn, so all gas giants initially sat within 15 AU of the Sun. It's believed a protoplanetary disk of planetesimals stretched from just beyond that boundary to about 30 AU. Asteroids seen today in the outer edge of the asteroid belt originally came from much farther out in the solar system so have retained water ice and other signatures. Asteroids in the inner portions were natives to the belt region.

A powerful lightning storm in Saturn's atmosphere since January has become the solar system's longest continuously observed thunderstorm. The storm is the ninth measured since Cassini began orbiting Saturn in July 2004. Lightning discharges in Saturn's atmosphere emit very powerful radio waves about 10,000 times stronger than their terrestrial counterparts and originate from huge thunderstorms with diameters of about 1,900 miles. The radio waves are useful to study Saturn's ionosphere.

In the wake of its most recent upgrade, a spectacular array of new images has shown the Hubble's new capabilities. Among the first images is galaxy NGC 6217. Hubble also snapped pictures of a group of five galaxies, a densely packed star cluster and an eerie "pillar of creation." In a new image of the Omega Centauri star cluster in our galaxy, the contrast between hot and cool stars can be seen. For the Butterfly Nebula, astronomers used new filters to see an envelope of gas expanding away from the planetary nebula. Scientists released spectroscopic observations slicing across billions of light-years to probe the cosmic-web structure of the universe and map distribution of elements key to life.

New pictures of Neptune's largest moon Triton, made from data taken by Voyager 2 on its way out of the solar system in 1989, reveal a surface covered with crater scars from years of space-rock impacts, as well as smooth volcanic plains, mounds and round pits formed by icy lava flows. The images were made using topographic maps derived from Voyager 2 photos. Voyager 2 revealed that Triton has active geysers.

From 1949 to 1961, Jupiter had a temporary satellite: Comet 147P/Kushida-Muramatsu, which was trapped in the planet's gravitational grip. There are only a handful of known comets where this phenomenon of temporary satellite capture has occurred and the capture duration in the case of Kushida-Muramatsu is the third longest. The comet has escaped from Jupiter. Astronomers have also confirmed a future Jupiter moon. Comet 111P/Helin-Roman-Crockett, which orbited Jupiter three times between 1967 and 1985, is due to complete six laps between 2068 and 2086. ■

Matloff continued from page 1

concentrate sunlight to aid in mining an asteroid.

As we researched the book, we learned a technology-development formalism called "technology readiness level" existed on the Web, but to our knowledge, not in print. "Living Off the Land in Space" may thus be the first book that outlines how a space technology advances from back-of-the-envelope calculation to readiness.

Because we were an art/science team, we also investigated the boundaries between art and science. After observing her work at a 2000 symposium of the International Academy of Astronautics in Aosta, Italy, the late Bob Forward convinced Les to fund C to create a prototype holographic interstellar-message plaque. Bob was more interested in the possibility of developing holographic coatings for solar sails. After viewing the art in 2001, MSFC staff members contributed to a technical study of holographic solar-photon sails. The boundary between art and science, at least here, was quite diffuse.

It's impossible to accurately predict the pace of space development and public-private funding mix. But as we describe in "Living Off the Land in Space," it's nice to see how relevant technology development performed by the NASA-MSFC in-space propulsion team is to future efforts to create settlements and industrial facilities in space. ■

AAA member Dr. Gregory Matloff is professor of physics at New York City College of Technology, CUNY, and a Hayden Associate at the AMNH.

Events on the Horizon
October 2009

M: members; P: open to the public; T: bring your telescopes, binoculars, etc.; C: cancelled if cloudy;
HQ: at AAA headquarters, Downtown Community Center, 120 Warren St.
AMNH: For ticket information, call (212) 769-5200

For directions to AAA observing events, check the club's website, www.aaa.org.

Friday, October 2, 6:15 p.m.
AAA lecture, (FREE), P
Michael Way, astronomer/computer scientist at NASA, will discuss "100 Years of Cosmology: From Spiral Nebulae to the Cosmic Microwave Background" in the AMNH's Kaufmann Theater. Next lecture: November 6.

Tuesdays, October 6, 13, 20, 27, 7:30 to 9:45 p.m.
Stargazing, High Line, Manhattan (FREE), P, T, C
Near the entrance at 14th Street and 10th Avenue.

Wednesdays, October 7, 14 and 28, and Saturdays October 3, 10, 17, 24 and 31, 8:30 to 10:30 p.m.
Observing at Inwood Hill Park, Manhattan, P, T, C
Next dates: Wednesdays and Saturdays in November.

Wednesday, October 7, 8 to 11 p.m.
Observing at Prospect Park, Brooklyn, P, T, C

Wednesday, October 7, 7 p.m.
New SciCafe at the AMNH, P—Music, cash bar
SciCafe and presentation first Wednesday of the month at Gottesman Hall of Planet Earth. AMNH astrophysicist Ben Oppenheimer will discuss exoplanets and the search for life, and how planets and solar systems form.

Friday, October 9, 8 to 10 p.m.
Observing at Floyd Bennett Field, Brooklyn, P,T, C
On model airplane flying field. Next date: November 6.

Saturday, October 10, Dusk to wee hours
Stargazing at North-South Lake, Haines Falls, N. Y. M, T, C Contact Rich Rosenberg at president@aaa.org.

Thursday, October 15, 6:30 to 8:30 p.m.
Recent Advances in Astronomy Seminar, M, HQ
Pre-meeting dinner at 5:15 at Gee Whiz Diner, Warren and Greenwich Sts. Next date: November 12.

Monday, October 19, 7:30 p.m.
Hayden Planetarium lecture, P, AMNH
University of Colorado professor Juri Toomre will discuss interplay of 3-D simulations and helioseismology.

Tuesday, October 20, Dusk to 10 p.m.
Observing at Cadman Plaza, Brooklyn, P, T, C

Wednesdays, October 21, 28, November 4, 11, 18, 25, 6:30 to 8:30 p.m. Six-week AAA class for beginners on descriptive astronomy, P, HQ
See president's letter on page 3 for details.

Wednesday, October 21, 8:30 to 10:30 p.m.
Observing at The Cloisters, Manhattan, P, T, C
Next date: November 18.

Friday, October 23, dusk to 10 p.m.
Observing at Carl Schurz Park, Manhattan, P, T, C

Saturday, October 24, dusk to 11 p.m.
Observing at Great Kills Gateway National Park, Staten Island, P, T, C On the model airplane flying field. Next date: November 21.

Tuesday, October 27, 6:30 to 8:30 p.m.
Observers' Group M, HQ
Pre-meeting dinner at 5:15 at Gee Whiz Diner, Warren and Greenwich Sts. Next date: November 24.

Saturday, October 31, 10 to noon
Solar Observing at Central Park, P, T, C
At Conservatory Waters. Next date: November 21.

Lectures continued from page 3

Gamow, Alpher, Herman, Zeldovich, Doroshkevich, Novikov, Peebles, Dicke, Adams, McKellar, Penzias and Wilson, among many others. There were many missed opportunities for discovering the background radiation and an almost comical manner in which two groups in the early 1960s, working only 30 miles apart, knew less about each other than Soviet scientists behind the Iron Curtain.

"The emphasis is of course historical, but also sociological. We'll see that science doesn't evolve in the linear manner that many, including many scientists, suppose, but is a messy process. Mindsets are also hard to change when confronted with a reality that differs greatly from currently received wisdom. These facts are the same today as they ever were, regardless of how enlightened we may feel we are."

Way, who has a Ph.D. in physics from the University of Missouri, has been with Goddard and Ames since 2000 . Since 2008, he's been a part-time visiting scientist in astronomy at Uppsala University in Sweden. He's also on the adjunct faculty of the physics department of Queens College, New York. Way earlier held positions at Princeton and Catholic University of Chile.

Other dates and speakers are:

November 6: Alan Guth, MIT, "Inflationary Cosmology: Is Our Universe Part of a Multiverse?" John Marshall Memorial Lecture.

December 4: Charles Baltay, Yale University, "Exploring the Dark Side of the Universe: Accelerating Universes, Dark Matter, Dark Energy and All That."

January 8: Jerry Bonnell, NASA, "Best Astronomy Pictures of the Day, 2008."

February 5: Arlin Crotts, Columbia University, "Liquid Mirror Telescopes Are Looking up."

March 5: John Gianforte, Blue Sky Observatory: "In the Footsteps of the Master: Discovering the Contributions of Galileo."

April 9: Glynnis Farrar, NYU: "High-Energy Astrophysics with a Neutrino Telescope in New York City."

May 7: Ruben Kier, Advanced Radiology Consultants, "Best Targets for Amateur Astrophotography." ■

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Forwarding and Address
Correction Requested

First Class