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The Giant Magellan Telescope Will be a Wonder to Behold

By Lynn Darsh

Wrapping up the 37th series of four Bampton Lectures in America April 14 at Columbia University, Wendy Freedman, director of the Carnegie Observatories in Pasadena, Calif., said astronomers are focused on making telescopes' next generation bigger than ever.

"The bigger the diameter of the mirror, of [these] light buckets, the more light we can collect, the further we can see and the higher resolution we can obtain," she said. "Most exciting new discoveries are unanticipated, and enabled by new technology."

Freedman chairs the board overseeing construction of the Giant Magellan Telescope (GMT). This next-generation, 25-meter-class optical telescope will be far larger than the largest existing telescope, which is 10 meters in diameter. An international consortium of 10 institutions has raised $250 million of the $700 million budget. Carnegie is the leading partner; others include the universities of Arizona, Chicago, Harvard and Texas at Austin, the Harvard/Smithsonian Astrophysical Observatory, Texas A&M, and institutions in Australia and South Korea. Only the latter two partners have government funding. The first observations are planned for 2019, and the consortium still seeks partners and donors.

The GMT would join Carnegie's twin Magellan 6.5-meter telescopes at Las Campanas, Chile. High in the unpolluted dry desert air of the Atacama Mountains, the GMT would enjoy 300 clear nights a year. Freedman called Las Campanas the best site in the world. The highest peak has been selected for the GMT.

Mirrors for the GMT are being fabricated at the University of Arizona. Sand to make the Borosilicate glass was collected on a Florida beach and sent to Japan to be baked in clay pots at 700 degrees Celsius and spun at five resolutions per second. The glass was cold polished for a year. Freedman called it "high technology mixed with medieval mirror polishing." Each of the seven 8.4-meter primaries, (six identical off-axis mirrors and one central on-axis mirror), is being made at the University of Arizona, using a unique honeycomb fabrication method developed there, and will weigh only 20% of what a solid mirror would weigh, yet still be firm.

The Magellan mirror will have a surface accuracy of 20 nanometers, which Freedman says will make it the best mirror ever made. The first mirror, the on-axis mirror, will be completed by the end of this year. Six other primary mirrors, all identical off-axis mirrors, will be placed around the on-axis mirror. Light from all seven primary mirrors will be brought to a common focus.

Each of seven secondary mirrors will be one meter in diameter and will correct one primary mirror for motion in our atmosphere about every one-thousandth of a second. This new take on an adaptive optics system will substantially improve the telescope's resolution.

The GMT's light-collecting area will be 100 times that of the Hubble Space Telescope. Spatial resolution will be 10 times greater than the Hubble's, because the GMT's mirror will be 10 times the diameter of the Hubble's. The GMT would be able to resolve the face of a dime in Boston from New York City. The enclosure, which will be built to allow air to circulate around the telescope to help maintain thermal equilibrium, will be 200 feet high, about 10 feet shorter than the Statue of Liberty.

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Come to the AAA's annual meeting Wednesday, May 18. See back page for details.

What's Up

By Tony Hoffman

The Sky for May 2011

Dance of the Dawn Planets. The first three weeks of May feature the year's best series of planetary conjunctions, as Mercury, Venus, Mars and Jupiter cluster in the predawn sky. On May 1, a thin crescent Moon joins the throng. That morning, Mercury lies 3 degrees to the lower left of Venus, while Jupiter lies below the Moon. Mars lies less than half a degree from Jupiter, but at magnitude 1.3 is too faint to see in the twilight. During the following days, Jupiter climbs to meet Venus, and on May 11 they stand 0.6 degrees apart, with Mercury 1.5 degrees to Venus' lower right. On May 22, Venus and Mars (still too faint to be seen) lie just over a degree apart. Jupiter steadily climbs out of the sunset glare, and should be very easy to spot by month's end.

May's Constellations. Saturn, the only one of the five planets known to the ancients not to participate in predawn conjunctions, puts on a show of its own this month. The planet, which came to opposition in early April, is still near its best, shining at magnitude 0.6 with its rings open about 8 degrees to our line of sight. It lies about 15 degrees from Spica, near the star Gamma Virginis. Virgo lies on the meridian about 11 p.m. at midmonth. To the west of Virgo, Leo is beginning to descend into the west, while Castor and Pollux stand side by side above the northwestern horizon in the early evening. The Big Dipper has passed the meridian and is beginning its swing into the northwest. Below Virgo lies the little quadrilateral of Corvus, the Crow. Well to Saturn's upper left is the bright orange star Arcturus.

Lyra, with its brilliant star Vega, swings out of the northeast, trailed by Cygnus with its brilliant star Deneb. Before midnight, Aquila rises almost due east. Its brightest star Altair, along with Deneb and Vega, form the asterism known as the Summer Triangle. To the southeast, Scorpius rises. Above Antares, a faint planetoid plies the star-cluster-rich bounds of southern Ophiuchus. You'll need at least an 8-inch telescope and a good star atlas to track down 14th magnitude Pluto.

May 1 Moon lies near Mercury, Venus, Mars and Jupiter in the morning sky.
May 3 New Moon at 2:51 a. m.
May 6 Eta Aquarid meteor shower peaks.
May 7 Mercury at greatest elongation in morning sky.
May 10 First-quarter Moon at 4:33 p. m.; Mercury lies near Jupiter.
May 11 Venus lies 0.6 degrees from Jupiter in morning sky.
May 14 Moon lies near Saturn.
May 15 Moon is at perigee, 225,000 miles from Earth, 7:24 a. m.
May 17 Full Moon at 7:09 a.m.
May 19 Mercury lies 2 degrees from Mars.
May 22 Venus lies 11 degrees from Mars.
May 24 Last-quarter Moon at 2:52 p. m.
May 29 Moon lies near Jupiter.
May 30 Moon lies near Mars and Venus.

I Had the Sun in the Morning And the Moon at Night

By Joseph A. Fedrick

March's full Moon occurred near the lunar perigee. It appeared rather large and didn't fit in the field of view of my 100x eyepiece or my 60 mm refractor. The waning crescent Moon that followed seemed a bit smaller and more nearly fit into the field of view.

Unfortunately, I didn't take any photos to demonstrate the difference of apparent lunar size between lunar perigee (full Moon) and lunar apogee (waning crescent moon).

The Sun became more active during March and early April. Toward the end of March, I saw two parallel bands of sunspots on the solar disk for the first time during the current sunspot cycle. I noticed that every time I viewed the Sun's projected image with my 60mm refractor, I saw spots on the image of the solar disk.

Saturn revealed a faint whitish zone in the 100x eyepiece of my 6mm refractor during March and April when the planet was near opposition.

The so-called winter constellations of Orion, Gemini, Taurus, etc. set earlier each night as winter turned into spring. ■

A Message from AAA President Richard Rosenberg

Hello members:

May is the month of our annual meeting, which will occur on Wednesday the 18th this year. I hope you'll take this opportunity to find out how the club is doing, and some of the exciting things that are going on. We'll meet at headquarters, 120 Warren St. in lower Manhattan, on the ground floor. Come at 6:30 for a buffet of sandwiches and salads.

The business meeting will begin at 7:30. Officers and event chairs will report on what we've done in the past year, as well as our goals for the future. Nominees for open positions on the board of directors will also be presented.

At the annual meeting, we want to hear from you! What are we doing well? What can be improved? If you're planning to attend, please contact me by e-mail or phone so we'll have an idea how many members will be present.

At a special meeting on May 11, the board of directors will meet to decide whether to approve a dues increase, and revisions to the club's bylaws. If the board approves either or both changes, the membership will vote at the annual meeting on whether to accept it/them.

If April isn't the cruelest month, it certainly is the rainiest. We've had a lot of washouts this past month. Let's hope May is better. Included in our observing sessions this month is a new location: Fort Tilden in the Rockaways. We'll be there on Saturday, May 7. We should have a view of nearly the entire sky in a dark location. I hope to see you there.

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

Gamma-ray Talk May 6 Wraps Up AAA's 2010-11 Lecture Series

David J. Thompson, a deputy project scientist for the Fermi Gamma-ray Space Telescope at NASA's Goddard Space Flight Center in Greenbelt, Md., will wrap up the AAA's 2010-11 lecture series Friday, May 6 when he speaks on "Exploring the Extreme Universe with the Fermi Gamma-ray Space Telescope." The free public lecture begins at 6:15 p. m. in the Kaufmann Theater of the AMNH.

"Gamma rays, the most energetic form of light, open a window onto some of the most extreme phenomena in the universe, because gamma rays can only be produced by high-energy processes," Thompson notes. "The Fermi Gamma-ray Space Telescope, launched in June 2008, views the entire sky every three hours, enabling a search for powerful transients like gamma-ray bursts, novae, solar flares and flaring active galactic nuclei, as well as long-term studies including pulsars, binary systems, supernova remnants and searches for predicted sources of gamma rays such as dark matter annihilation."

Thompson has worked as an astrophysicist at Goddard since 1973. He's a graduate of Johns Hopkins and holds a Ph.D. in physics from the University of Maryland. Thompson has worked in all aspects of observational gamma-ray astrophysics: designing, building, testing and operating balloon and satellite gamma-ray telescopes, and analyzing and interpreting results from those telescopes. In 2009, he participated in a History Channel episode of "Universe" about pulsars and quasars. ■

AAA Nominating Committee Backs 7 for Board of Directors

The AAA nominating committee last month recommended four incumbents to serve three-year terms on the board of directors. They are treasurer Thomas Haeberle, former president Michael O'Gara, Bruce Kamiat and Shana Tribiano. The committee also recommended former board member Susan Andreoli and newcomer Evan Schneider for three-year terms. They would replace Rik Davis and Gerceida Jones. Leo Genn was tapped to fill the remaining two years of the term of Alice Barner, who recently resigned. The committee consisted of board member Marcelo Cabrera (chair), president Richard Rosenberg and board member Joe Delfausse. ■

Use Space to Alleviate Global Warming, Speaker Says

By Dan Harrison

Global warming can be alleviated by using natural and man-made objects in space to reduce sunlight, Prof. Greg Matloff told the AAA April 1.

Speaking at the AMNH on "Regreening the Earth Using Space Resources," Matloff, an AAA member who's associate professor emeritus and adjunct associate professor of physics at New York City College of Technology, CUNY, noted that people don't want to change the way they live, so "the challenge is altering global warming without altering global lifestyles."

One idea is creation of a sunshade by drawing a near-Earth object (NEO) to Earth's Lagrange L1 point, 1 million miles closer to the Sun than to Earth. The disassembled NEO is reformed into a sail-like sunshade.

This approach would involve placing a thin sail-like structure, about 1,000 kilometers across, which would reduce sunlight by a small amount in an eclipse effect.

Instead of one large sail-like structure, Matloff noted, there could also be thousands of so-called Dyson dots, each a small sail placed at L1. "These could also act as solar-flare warning stations," he observed.

On a broader level, Matloff said space resources can not only be used to help us in space, but on Earth.

"If we're going to survive, we have to learn how to exploit the resources of the solar system and, to some extent, get rid of waste products. Why do power plants have to heat our environment? Why not locate them in space and radiate the waste heat into space?"

In Matloff's view, the game changer in preventing a catastrophe is NEO diversions. "Politicians are starting to take this seriously. Scientists have for a long time."

In 2029, asteroid Apophis will pass near Earth. The size of three football fields, it will pass within the orbits of geosynchronous satellites. The chances of an impact are virtually nil, Matloff noted, but the rock will come closer in 2036. "We have no idea what this large body is like, but if it hits in an ocean, which is likely, 40 million to 50 million people would be killed and the Japanese tsunami would be a ripple in a bathtub."

Apophis could calve into other objects, one of which could hit us. If it puts out a tail, its trajectory could be altered. If we smash something into it at 60 km/second, Matloff said, we have to hope it doesn't fragment.

Various deflection schemes have been discussed. Nuclear would work with certain types of asteroids, such as iron-rich, but silicate or carbonaceous chondrite, for example, may just fragment. Solar sails could slightly deflect an asteroid. "Apophis is probably some type of chondrite but we don't have a lot of data as yet."

Big asteroids such as Apophis can be moved, but it's much easier with small ones, which can be mined. "If we're going to move them, why not use them?" Certain types of asteroids can be steered into high Earth orbit.

Since most of space is sterile, exploiting objects with no life wouldn't interfere with objects where there may be life. We could have cosmic factories on lifeless objects, making use of materials that could be garnered elsewhere. NEO material could be used for rocket fuel, cosmic-ray shielding, oxygen, and water in space for life support for such terrestrial applications as solar-powered satellites and sunshades.

The mass of solar-powered satellites in geosynchronous orbit has declined considerably. Energy could be beamed down by laser or microwave. The Japanese have already tested solar sails and hyperthin solar panels.

"The initial satellites would probably be Earth-launched, but down the line there would be no reason why we can't garner the material for these from NEOs. If we have to move NEOs and if the economy says space solar power is the way to go, why not do both?"

"We have the physics to move NEOs, and the ability to construct solar power stations and some type of Dyson dots. The physics is there, and we almost certainly will have the technology within 10 years. Do we have the collective will as a society to do it?" ■

Just What Does It Take to Form a Habitable Planet?

By Anne Kiefer

The latest findings of the Kepler Mission, released in February, ignited the scientific community when it was announced that 54 planetary candidates within habitable zones had been discovered, including five less than twice the size of Earth. Of course, this doesn't mean it's time to pack our bags for Earth II. But it brings up an important question: What does it take to create a habitable planet? What factors will turn a budding planet into something like Earth instead of something like Jupiter?

This was the question explored at an April 11 Hayden lecture, "The Hitchhiker's Guide to Habitable Planets in Our Galaxy." Linda Elkins-Tanton, professor of geology in the Department of Earth, Atmospheric and Planetary Sciences at MIT, explained the rare and fortuitous circumstances required to produce a habitable planet.

She started with an important admission: "Do we know what life is? Not really. Do we know what life requires? Not really." If this is the case, how do we even begin to touch on the idea of what is habitable? Since we only have ourselves to study, we have to look at the idea of what's habitable for Earth-like life.

That said, we know three major elements are required for a terrestrial planet to be habitable: water, carbon and plate tectonics to renew the atmosphere and control levels of gases in it. This last factor is one of the major reasons Earth is habitable and Venus isn't.

Recent discoveries demonstrate that planets are far more common than once thought. We now know that every star forms with a planetary system around it. That leaves us with an incalculable number of planets, but it takes a very fortuitous series of events to create a rocky planet with the attributes that support life.

Elkins-Tanton laid out a timeline of the many millions of years it takes to build a planet. She wove interesting explanations as well as historical context into the complicated narrative of planet formation.

"We're all made from stardust," Elkins-Tanton said—or, more specifically, all substances that make up life on Earth are the result of stellar activity. The birth of any planetary system begins with the birth of a star. When a diffuse cloud of gas and dust is hit with the energy burst of a nearby supernova, the cloud collapses on itself to form a star. The remaining gas and dust is left spinning around the star, creating a protoplanetary disk and, eventually, a planetary system.

What happens during the disk stage is vital to determine what kind of planets will form from the spinning gas and dust, Elkins-Tanton stressed. It's a very narrow window--10 million-20 million years--which, in the context of a planet's lifespan, is very fleeting. To put this in perspective, Earth is about 4.5 billion years old.

During this stage, interplanetary dust, often described by scientists as "fluffy," clumps together to form the beginnings of planets. These small clumps continue to collide and coagulate in the rotating cloud, growing in size with each collision.

This brings us to one part of the planet-building process that historically was a mystery to scientists. Only recently have viable explanations been formulated. The dust clumps, called planetesimals, continue to grow until they reach one meter in diameter. At this point, planet embryos are large enough that they don't stick together; their collisions begin to be destructive. It isn't until they reach one kilometer in diameter that they have sufficient mass to create a gravitational field significant enough to keep two colliding planetesimals together.

Elkins-Tanton posed a hypothesis of how this leap in size is explained using the idea of Kelvin-Helmholtz instability. She explained that turbulence is created as the dust settles in the center of the disk. The flow of the dust-laden portion of the disk is slower than the more viscous gas flows that sandwich it. This fosters a turbulent environment that stimulates the dust to clump to larger sizes than one meter.

Elkins-Tanton demonstrated this with a video, showing rotating planetesimals growing and clumping together in a turbulent environment. The planetesimals can grow to the size of Utah, and be significant enough to rely on their gravitational forces for continued growth. ■

After Circuitous Flight, MESSENGER Enters Mercury Orbit

By Jason Kendall

On March 17, MESSENGER became the first spacecraft to enter Mercury orbit. NASA TV streamed the event live via webcast and the AMNH created a special event for that evening. Dr. Denton Ebel, curator in charge of the AMNH's Department of Earth and Planetary Sciences, led a museum team in hosting the event. I acted as the NASA/JPL Solar System Ambassador to the proceedings.

The event was important for the MESSENGER (MErcury Surface, Space ENvironment, GEochemistry and Ranging) team because it was the conclusion of a long, involved flight. Launched in August 2004, the car-sized spacecraft used numerous gravity assists and deep-space maneuvers to arrive at the hot world almost seven years later. Flying by Earth once, Venus twice and Mercury three times, the craft's final flight plan was to burn the main engine for 15 minutes to slow MESSENGER enough to be captured by Mercury into orbit. An SRO crowd of 250 applauded each event. I reported to attendees about events on Twitter, because the NASA webcast lagged two minutes behind the Twitter feed.

At 9:11 p. m., confirmation of main-engine shutdown occurred, I reported it to the crowd, and they had an extra dose of the event. Many attendees brought their laptops, Droids and iPhones to put the event on Twitter and Facebook to their friends. The social-media aspect of the event was important, with NASA covering the event from numerous locations. Extensive use of many simultaneous outlets, with people in the same room watching an event in many formats, is becoming a fixture in many live NASA events.

Participating from the museum's perspective on conference call, Dr. Carter Emmart, director of astrovisualization, led his Digital Universe "flyer" Brian Levine of the AMNH education department through MESSENGER's trajectory with the Hayden's 3-D space-simulation software. We were able to replay the event as though viewing it from space. Accurately showing the orbital insertion, and orbits to come, Emmart and Levine showed the crowd how MESSENGER would take its science data. Unfortunately, the data set for the flyby won't be available on the Hayden's public website.

Ebel presented a slide show about the spacecraft itself, showing its construction and science instruments. He also outlined the mission's core goals. Scientists have been aching to get back to Mercury since the three flybys of Mariner 10 in 1974. Most of the planet wasn't imaged, and a variety of discoveries tantalized astronomers for decades, including a magnetic field and tenuous atmosphere.

With the explosion of exoplanet discoveries, Mercury holds many keys to understanding the formation of terrestrial planets, helping us understand how the solar system fits in with all forms of planetary-system formation.

Mercury is the most extreme planet of the inner solar system: smallest, densest, oldest surface, largest daily temperature variations and least explored. The MESSENGER mission seeks to learn why Mercury is so dense. It has a metal-rich core which takes up about two-thirds of the planet's mass.

The mission also wants to learn Mercury's geologic history. By studying formations and features of the surface, past volcanism, meteoritic impacts and tectonic activity can be deduced. Next up will be the magnetic field. Mercury's global field is about 1% the strength of Earth's, but at least it has one, unlike Mars and Venus. Characterizing the magnetic field will help determine formation differences between rocky planets.

Related to characterizing the magnetic field will be determining the structure of Mercury's core. Combining gravimetric measurements and accurate laser altimetry will determine the size of the core, and verify whether the outer core is molten, like Earth.

Next, MESSENGER will measure the composition of Mercury's tenuous exosphere. An exosphere is like an atmosphere, but is so thin that atoms, molecules and ions never collide. They simply follow ballistic up-down trajectories over Mercury, or escape altogether with the solar wind. Determining the composition of the exosphere will illuminate processes that caused its existence.

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Review: Going Au Courant with an Interactive Book for iPad

By Edward J. Fox

In this day of computers, tablets, smart phones and other electronic gadgets, there's a new electronic-only astronomy book, "Solar System for iPad," by Marcus Chown (Touch Press LLP, Version 1.0.0, 842 MB, $13.99).

In keeping with the capabilities of the electronic medium, this is an interactive book for an iPad. It is a collaboration of the writer, Marcus Chown, a scientist and renowned science writer, and a team at Touch Press, a digital book company, most recently acclaimed for the electronic book "The Elements." Touch Press is evaluating other platforms, including Android tablets, for future development of e-books.

The production values are first rate, encompassing fine writing, computer animations and effects, and hundreds of photographs. The credits pages are similar to those of a major motion picture, containing columns of technical and institutional contributors.

Even the table of contents is an electronic work of art. It pays homage to the Periodic Table of Elements in its arrangement of solar-system objects. The Sun, planets, asteroid belt, Kuiper Belt and Oort cloud are arranged in a row across the top, with columns of moons and minor objects appropriately arranged. All are rotating icons.

Also available is a slider icon at the bottom of each page, which opens a gallery of images of an object at hand, such as the Sun, as well as a direct-tie-in online to Wolfram|Alpha, for the latest information about an object. The icon can also slide along a graphic scale to open pages about any object in the book.

What these interfaces lead to, in an open formatted and flexible way, is 150 pages of well-written "stories" about the objects and the solar system's history. Planets and other objects are fully rotatable and, in some cases, interiors can be exposed. There are 600 images from NASA, ESA and JAXA missions. More than 40 3-D objects are pinch-zoomable and rotatable. Clicking on picture captions leads to more information about the subject.

One of the best animations is Orrery, a digital model of the solar system. Clicking on a thumbnail icon, on the upper right of major pages, brings up a moving image of planets. Clicking on a planet zooms to it and its moons. It's an elaborate digital version of the antique ivory and brass orreries that were made to illustrate Copernicus' insight that the Earth orbits the Sun.

Animation is rotatable and scalable. A slide scale at the bottom can vary the scaled passage of time in variables of real time (one second equals a day or a month, etc). Text describes how this model cannot be and isn't a true picture of sizes and distances in the solar system.

A YouTube video of the author describing and demonstrating the book is available at http://www.youtube.com/watch?v=DDwnHP-tUz0.

Chown points out some particular features of his book, including a simulation fly-through of the canyon on Mars, which is so large that its tributaries are the size of the Grand Canyon; animation of the atmosphere of Jupiter and its mega storms; and how the Jupiter's moon, Io, for its size, is the most heat producing solar-system object due to the squeezing effect of Jupiter's gravitational pull.

Considering the low price, this is a first-rate investment for learning about the solar system. It's a production that no textbook or coffee table book can match. In Chown's words, "It is something new under the Sun." ■

Space Exhibition to Debut at the AMNH

"Exploring Space," a new exhibition at the American Museum of Natural History, opens November 19 and runs through August 12, 2012.

The exhibition will focus on the future of space exploration as it speculates on humanity's next steps in the solar system and beyond. It will feature a full-size recreation of a lunar habitat, a model of an elevator reaching into space, a walk-through diorama of the Martian sur-

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Additional light-gathering power and resolution are key to making the next generation of discoveries, Freedman noted. Exoplanets are extremely faint objects that shine from the reflected light of their stars. They appear about one billionth as bright as the Sun. The GMT will try to achieve unprecedented resolution and sensitivity to directly image exoplanets found by the Kepler Space Telescope using other techniques.

Kepler's findings have yielded surprises, Freedman said. The theory of planet formation has been overturned. Our solar system's planets have nearly circular orbits, almost in the same plane, with the larger planets farthest out. Kepler has found massive planets orbiting close to their stars, in very elongated orbits that aren't in a single plane. If the GMT is large enough to take detailed enough spectra of exoplanets, signatures such as carbon dioxide can be found, and the study of exoplanet biology, not just chemistry, will become possible.

The GMT can be an important partner to other telescopes as well as Kepler, Freedman observed. While the Hubble operates in optical and ultraviolet, its successor is the James Webb Space Telescope, a 6.5-meter infrared telescope due to launch in 2016.

The Large Synoptic Survey Telescope, due to be operational in 2018 in Chile, will try to discover a couple of million supernovae in the search to measure dark energy. The GMT is needed to provide accurate spectra of these supernovae, and make measurements of the expansion of the universe and the acceleration of that expansion.

The Atacama Large Millimeter Array, a high-resolution, several-dish radio telescope, will begin operations in 2014, peering into central star-forming regions of high-redshift galaxies. The Square Kilometer Array is planned for the Southern Hemisphere. The GMT would have huge synergies with both radio telescopes.

"Discoveries that we make when we have new technology are largely unanticipated, and it is what keeps us as scientists very interested in building that next generation of telescopes," Freedman said. "In the 21st Century, we…are uniquely positioned to study…the cosmic dawn, the early moments of the universe…see directly galaxies forming and merging, how that whole assembly took place, planets beyond the solar system, Earth-like planets and perhaps even life elsewhere in the galaxy."

Freedman's second Bampton lecture April 7 at Columbia was on "Dark Matter: Much More than Meets the Eye." She explained why stars, galaxies and galaxy clusters are in motion, how Newton's Law of Gravity describes this motion well and that "Dark matter rules."

Today's observers see the universe as lumpy; in scientific terms, inhomogenous and anistrophic, filled with stars, galaxies and galaxy clusters, Freedman stated. Theorists see it as homogenous and isotropic, full of dark energy and dark matter. Cosmologists think only 4% of the universe is ordinary matter, and their first evidence is based on galaxy kinematics. Additional evidence came from Einstein urging astronomers, in 1913, to measure the effect of gravity on starlight.

What is dark matter? So far, failed planets, remnants of stars that have exhausted their nuclear fuel, hot and cold gas, massive compact objects in the outer reaches of galaxies, black holes and dust have been ruled out. There may be a relic particle, "formed in the Big Bang and not yet discovered in laboratories, that interacts with gravity but doesn't emit radiation. [This particle would interact] very weakly with ordinary matter, but it doesn't shine."

Many scientists are seeking evidence of dark matter. Some use germanium and silicon detectors, "buried in mines, shielded with lead," and are "searching for gamma rays that could be an indirect signal of dark matter. Others are looking with the Fermi Gamma-ray Space Telescope for a signal of the annihilation of dark matter near the center of the Milky Way."

The Large Hadron Collider will spend the next decade searching for evidence of dark matter in the scattering of particles by "smashing two protons together confined with strong magnetic fields and creating conditions comparable to those in the Big Bang." Physicists hope to find the evidence in particles that only exist for a short time.

In the third Bampton lecture April 12, Freedman spoke on "A Runaway Universe: The Universal Accel-

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erator: Dark Energy in the Universe." She was leader of the Hubble Space Telescope Key Project, which determined the age and size of the universe, and the Hubble Constant to a precision of 5%.

The universe's accelerating expansion can be explained by Einstein's theory of gravity (the cosmological constant, the fudge factor he used to force the universe to be static), or not. There could be "repulsive gravity."

Newton's Law of Gravity, that "the force of gravity depends on the mass of an object and falls inversely as the square of the distance," has what Freedman called "the unappealing aspect of action at a distance." The early 20th century view of the universe (the Milky Way) was that it was static, governed by Newton's gravity, and space and time are absolute. In Einstein's universe, "Matter tells space how to curve and space tells matter how to move. The universe's evolution can be determined by the General Theory of Relativity and tested by experiment."

Dark matter's existence is inferred by gravitational attractions and use of Newton's laws of gravity, Freedman said. "We can make those measurements by studying motions of stars within galaxies and galaxies within clusters, X-ray gas in clusters, bending of light as predicted by Einstein and other techniques. Not only is the universe expanding, it's expansion is accelerating, and we don't yet have an explanation. It may be what Einstein originally predicted…and it may be consistent with Einstein's gravity after all, but we don't yet know. It's an unsolved scientific question."

By Evan Schneider

Freedman opened the Bampton lecture series at the AMNH April 5 with "The Scale of the Universe." She studies dark energy by observing supernovae. Her goal is further understanding of how our universe expands and a redefinition of the Hubble Constant.

To demonstrate the universe's scale, Freedman provided visual comparisons of our solar system's planets to the Sun and our solar system to giants such as Betelgeuse and Antares. This underscored how small we are vs. other planets and stars. The scale of our solar system becomes clearer when we see it takes 100,000 light-years to traverse the Milky Way. There are 100 billion stars in the galaxy and 100 billion galaxies in the universe.

What about the composition of stars and planets? Hydrogen and helium were the principal elements in the Big Bang, Freedman explained, as evidenced by looking back to 400 million years after the Big Bang with the Hubble deep-sky image and cosmic-microwave-background data. Remaining elements were formed out of the universe's evolution from hot gases and dust, and through accretion and gravity processes, finally forming planets and stars we see today.

Dark matter and dark energy may be causing the universe's faster acceleration. In fact, the universe is expanding faster at greater distances than nearby. No data have enabled us to understand why this is occurring.

To describe the evolution of the universe, Freedman said, we first look to the Friedman Equation, stating that the rate of expansion (Hubble Constant) is equal to mass/gravity (amount of matter in the universe) minus the geometry of the universe (allowing for curvature of space) plus vacuum energy density. The latter, Einstein's Cosmological Constant, established a static universe, which we now can challenge due to Hubble observations.

Henrietta Leavitt's law, addressing the time a Cepheid variable takes to pulsate, showed it's directly related to its average brightness: The longer the pulsation period, the brighter the star. This relationship allowed astronomers to use Cepheid variables as standard candles to measure distances within our galaxy and to nearby galaxies. Measure distances over time and we can plot the rate of universal expansion.

The universe's diameter has been figured at 45.7 billion light-years. We can look back 13.7 billion light-years and combine that with the calculated rate of expansion. The scale has been set, but faster acceleration brings a "new epoch" to the universe's evolution.

As galaxies expand at increasing speed, 60 billion years from now our descendants will see only galaxies gravitationally bound to ours. The remaining universe will have sped out of sight. This provides the ultimate definition of the scale of our universe: boundless. ■

Briefs: 1st Galaxies May Have Formed Earlier than Thought

The first galaxies may have formed much earlier than thought, just 200 million years or so after the universe's birth, a new study suggests. Using several telescopes, astronomers discovered a galaxy born about 300 million years earlier than the oldest previously known galaxies. The newfound galaxy isn't the farthest-flung galaxy ever detected. Several with younger stars have been spotted at greater distances. Astronomers detected the galaxy through a cluster of galaxies called Abell 383. The alignment of the newfound galaxy, Abell 383 and Earth amplified the galaxy's light. Without this big lens in space, scientists couldn't study galaxies this faint with current observing facilities. In analyzing the galaxy's light, a team determined its redshift. The galaxy's redshift was 6.027, indicating astronomers are viewing it the way it appeared when the universe was some 950 million years old. However, the galaxy's stars appear to be at least 750 million years old, meaning they must have formed just 200 million years or so after the Big Bang. That's a few hundred million years earlier than astronomers had thought galaxy formation started. Other studies had detected farther-flung galaxies that seem to have formed about 500 million years after the universe's birth. This confirms earlier observations that hinted at the presence of old stars in early galaxies, and suggests the first galaxies have been around a lot longer than previously thought. The discovery has implications beyond when galaxies first formed. It may help explain how the universe became "reionized." About 300,000 years after the Big Bang, hydrogen was neutral, meaning it carried no charge. Over the course of the next 1 billion years, something threw off enough radiation to ionize most of the hydrogen, splitting it into electrons and protons. This made hydrogen transparent to ultraviolet light, clearing the "fog" of the early universe.

While astronomers are largely baffled by the question of how the universe began, they should probably hurry up and figure it out. In the far future, most of the evidence will be long gone, a new study suggests. Although future astronomers will likely have the benefit of advanced technology and a more sophisticated understanding of physics, they won't be able to take advantage of the last vestiges of evidence left over from the Big Bang. The trace signals from the explosion that set the universe in motion will likely be gone 1 trillion years from now. By that time, the Milky Way will have collided with Andromeda to create the Milkomeda galaxy. However, researchers have identified some backup clues that our distant descendants could use to trace the history of the universe. Astronomers today can look at galaxies more than 13 billion years away that were formed only millions of years after the universe began. They can also study the so-called cosmic microwave background radiation. However, in the distant future, these clues won't be visible to scientists on Earth or its near environs. The cosmic microwave background light will have faded away and stretched to the point that its particles of light, called photons, will have wavelengths longer than the visible universe. And because the universe is expanding, ancient galaxies now just within our field of view will be too far away to see. The Sun and many stars will have burned out, and our cosmic neighborhood will be much emptier than today. However, all hope for future celestial sleuths is not lost, because astronomers might be able to study the Big Bang through so-called hypervelocity stars that have been flung out of the Milkomeda galaxy. These stars will be the most distant light sources visible to astronomers in our galaxy in the year 1 trillion A.D.

Future astronomers won't have to take the Big Bang on faith. With careful measurements and clever analysis, they can find the subtle evidence outlining the history of the universe. The first spacecraft to circle Mercury beamed home the first-ever photo taken of the small rocky planet from orbit, showing a stark landscape peppered with craters. NASA's MESSENGER spacecraft snapped the photo March 29. It shows the stark gray landscape of southern Mercury, a view dominated by a huge impact crater. The new photo shows a region around the South Pole. A 53-mile-wide crater stands out, with bright rays emanating from its center. A smaller crater, 15 miles wide and known for its unusual dark rays, is also visible. The photo is the first of 363 shots MESSENGER took during six hours of observations. The images are expected to cover previously unseen areas. MESSENGER is expected to spend at least a year studying Mercury from orbit. The craft's extremely elliptical orbit brings it within 124 miles of Mercury and retreats to more than 9,300 miles away. MESSENGER will map the entire surface, a process expected to require 75,000 images. Scientists hope the spacecraft will help

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Briefs: Stardust Spacecraft Put to Death After 12 Years

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answer mysteries about the planet's geology, formation and history. *(For more on MESSENGER, see Jason Kendall's story on page 6.)*

NASA's comet-visiting Stardust spacecraft was put to death in March after more than 12 years. The craft visited two comets, returning pieces of one to Earth and traveling nearly 5.7 billion miles. It launched in 1999 on a mission to retrieve the first samples of a comet. The probe zipped by comet Wild 2 in 2004, flying through the coma and snagging particles. Two years later, Stardust ejected its sample-carrying capsule to Earth. The craft rendezvoused with comet Tempel 1 in 2005 and took photos of the scar left by a Deep Impact probe that year. Stardust information will assist current spacecraft, providing a better predictor of when fuel may run out. For future missions, better placement of pressure and temperature sensors might improve computer modeling.

Scientists have pieced together the most accurate and detailed map of the entire Moon, using photos from NASA's Lunar Reconnaissance Orbiter. The map is a mosaic stitched together from thousands of pictures taken by the Lunar Reconnaissance Orbiter Camera. The map was created using more than 15,000 photos taken between November 2009 and February 2011. They were taken when the Sun was relatively close to the lunar horizon, a good position for bringing out details of topography. The global view has a resolution of 328 feet per pixel, with accuracy to match, so the position of individual features can be determined to within 328 feet.

Asteroid 2005 YU55, a round mini-world 1,300 feet in diameter, will approach Earth within 0.85 lunar distances November 8. Extensive radar, visual and infrared observations are planned. With new radar capabilities, there's a good chance of obtaining imaging down to the 5-meter resolution level. Because of its size and proximity to Earth, the asteroid's been designated potentially hazardous. To help coordinate observing, websites have been set up. The flyby will be the closest by any near-Earth asteroid with an absolute magnitude this bright since 1976 and until 2028. Nobody saw 2010 XC15 during its flyby within 0.5 lunar distances in 1976, so 2005 YU55's flyby will be the closest observation of something this large. It will provide imaging resolution comparable to or better than a spacecraft flyby. With the asteroid so close, radar echoes will be extremely strong. Such information can be transformed into 3-D shapes, with surface features and spin rates identified. Roughness and density can also be assessed. And radar can improve the orbital calculations for the object. Amateurs will be able to see the asteroid with small telescopes. Initially, it will be too close to the Sun and too faint for optical observers. But late in the day (UT) November 8, solar elongation will grow sufficiently to see it. Early November 9, the asteroid could reach 11th magnitude for several hours before it fades as its distance rapidly increases.

NASA and co-researchers from the U. S., South Korea and Japan have found a new mineral named wassonite in an historically significant meteorite recovered in Antarctica in 1969, the same year as other landmark meteorites were found and the first Apollo lunar samples were returned. The meteorite may have originated from an asteroid orbiting between Mars and Jupiter. Wassonite is among the tiniest, yet most important, minerals identified in the 4.5-billion-year-old sample. It's a mineral formed from only sulfur and titanium, yet with a unique crystal structure not previously observed. Researchers found wassonite surrounded by unknown minerals that are being investigated. The mineral is less than one-hundredth the width of a human hair. It couldn't have been discovered without NASA's transmission-electron microscope. John T. Wasson was a UCLA professor known for achievements in meteorite and impact research, including use of neutron-activation data to classify meteorites and to formulate models for chemical makeup of bulk chondrites. Meteorites, and minerals within them, are windows to solar-system formation.

Amateur astrophotographs online are being utilized by professionals. For a short time in 2007, Comet 17P/Holmes became the solar system's largest object as the thin ball of dust and gas surrounding it briefly became larger than the Sun. At that time, Holmes brightened by a factor of half a million, making it visible to the naked eye. This seems to have been caused by a sudden outburst of gas from the comet's nucleus. This triggered

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Briefs: Data on Universe Growth Back Dark-Energy Theory

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huge interest from astrophotographers, with many posting their images. To find out how many, Princeton's Dustin Lang and David Hogg at the Max-Planck-Institut fur Astronomie in Heidelberg, Germany, searched the Web, finding 2,476 shots of Holmes. Today, they use these images to work out an accurate orbit, a significant achievement given that data are taken from an ordinary Web search and their provenance is unknown. The two fed each image into a website which analyzes the pattern of stars in the shot, then reveals which part of the sky it shows. They then created a giant montage of these images, carefully superimposing the stars. Since the pictures were taken at different times, the superimposed images show the comet moving across the sky. The two then compared the trajectory of the comet with the orbit calculated by the JPL and found a remarkably close match.

Twin jets of gas shooting from opposite sides of a young star may appear symmetrical, but they actually blasted into space 4 1/2 years apart. Astronomers used Spitzer to take a closer look, only to discover knots of gas and dust from one jet are ejected years later than from its twin. The finding should help astronomers understand how jets are produced around blossoming stars, including ones that resemble our Sun when it was young. Researchers think communication occurs between the jets, which may be carried by sound waves through the disk of material surrounding the star. Young stars typically emit high-speed jets of gas during an active phase in their evolution. The jets' discovery also helped astronomers measure the size of the zone from which the jets originate, which is limited to a circle around the young star 10 times smaller than previous estimates. One jet had been long studied, but its twin remained hidden behind a dark cloud. Spitzer's infrared instruments peered through the dusty cloud to see the second jet. Other symmetrical jets have been seen before, but it's unknown if they experience time delays.

New measurements of the universe's expansion rate lend support for a dark-energy theory that suggests a mysterious force is pulling the cosmos apart at ever-faster speeds. Researchers calculated how fast the universe is expanding to a greater degree of accuracy, thanks to the Hubble's Wide Field Camera 3. They observed type 1a supernovas, useful because they always release the same amount of light. Astronomers compare this intrinsic brightness to measured brightness, which varies depending on how far from Earth supernovae are, to judge cosmic distances. That the universe is apparently expanding ever faster is unexpected based on current laws of gravity, namely Einstein's theory of general relativity.

When Cassini photos showed a large patch near Titan's equator mysteriously darken, then grow lighter within a couple of weeks, scientists found something unexpected: a methane rainstorm in an area thought covered by vast, arid dunes. While the moon has methane lakes at its poles, scientists thought Titan's equatorial region was mostly dry. Cause of the darkness was likely an outburst of clouds and methane rain. The poles are the only places where liquid lakes and seas have been seen, and there's cloud activity at the South Pole. Equatorial latitudes are mostly arid. The large methane storm occurred around the time of the equinox, which suggests Titan has seasonal weather changes, with clouds at high latitudes near the South Pole moving across the equator and eventually into the northern hemisphere as seasons change. The findings seem to indicate tropical rainfall occurs more regularly with the seasonal cycle, although the interval between two wet seasons is 15 years due to Saturn's long orbital period.

Scientists working with data from NASA's Cassini, Galileo and New Horizons missions have traced ripples in the rings of Saturn and Jupiter to collisions with cometary fragments more than 10 years ago. In Jupiter's case, the culprit was comet Shoemaker-Levy 9, which hit in 1994. Scientists attribute Saturn's ripples to a similar object—likely another cloud of comet debris--plunging through the inner rings in 1983. Scientists know collisions into the rings are common: a few times per decade for Jupiter and a few times per century for Saturn. Ripples also give clues to the size of clouds of cometary debris that hit the rings. In each case, nuclei of the comets, before they likely broke apart, were a few kilometers wide.

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Just a few months after scientists presented evidence of ice volcanoes reshaping the surface of Titan, Saturn's largest moon, a new study is throwing cold water on the prospect. Scientists say Titan's identifiable surface features were likely created by weather or other external forces--meteorite strikes, wind and rain--rather than volcanic activity. This suggests the Moon's interior may be cool and dormant, incapable of causing active ice volcanoes. In December, researchers studying Cassini observations said they'd found solid evidence of ice volcanoes. Icy volcanoes are known to exist on Enceladus, and some researchers think they may be common on frigid satellites of the outer solar system.

Roughly one out of every 37 to one out of every 70 Sunlike stars might harbor an alien Earth, a new study reveals. This hints billions of Earthlike planets might exist in our galaxy. New calculations are based on data from Kepler, which in February revealed more than 1,200 possible alien worlds, including 68 potentially Earth-size planets. JPL scientists focused on roughly Earth-size planets in the habitable zones of their stars. After researchers analyzed four months of data in these initial Kepler readings, they determined 1.4%-2.7% of all Sunlike stars are expected to have Earthlike planets, ones between 0.8 and two times Earth's diameter and in the habitable zones of their stars. This means there are 2 billion Earth analogs in the Milky Way. After 3-4 years of Kepler data are investigated, scientists predict 12 Earthlike worlds will be found. Four have already been seen in four months of data. Of the 100 nearest Sunlike stars within a few dozen light-years, findings suggest only about two might have Earthlike worlds. But red dwarfs might host Earthlike planets as well, and such stars are far more common than Sunlike stars.

A NASA probe has created the most detailed view yet of the far side of the Moon. The Lunar Reconnaissance Orbiter took the picture, actually a mosaic of thousands of lunar far-side images. The picture provides the most complete look at the history and composition of the far side. Tidal forces between the Moon and Earth have affected the Moon's rotation so it only presents one side to us. The far side remained hidden until 1959. Since then, scientists have learned the far side is very different than the near side. Widespread basaltic plains called maria, deposited by volcanic activity long ago, cover much of the near side. But basaltic volcanism was much more limited on the far side, so the region sports just a few isolated maria.

Saturn is emitting radio signals. They differ in the northern and southern hemispheres, which can affect how scientists measure length of a Saturnian day. Signal variations, controlled by Saturn's rotation, also change dramatically over time, apparently in sync with the seasons. Scientists thought they understood radio-wave patterns at gas giants, since Jupiter was so straightforward. While Saturn's waves are inaudible to human ears, to Cassini they sound like bursts of an air-raid siren and vary with each rotation. Scientists have converted radio-wave emissions to the human audio range.

Astronomers have detected a new candidate for the coldest known star. The object, a brown dwarf, is the dimmer member of a binary brown-dwarf system 75 light-years away. This brown-dwarf binary system's temperature is the coolest found. The dimmer of the two stars has a temperature of about 212 degrees. At such temperatures, scientists expect the brown dwarf to have properties different from previously known brown dwarfs and much closer to those of giant exoplanets. It could even have water clouds in its atmosphere.

There may be worlds that float through intergalactic space without stars to warm them. Such planets might seem too cold and dark to ever be homes for life. But dark matter could help make these starless planets habitable, a new study suggests. Researchers created a 3D map of dark matter in a large portion of the universe by combining gravitational lensing data from more than 500,000 galaxies. Among the leading candidates for what dark matter is are massive particles that only rarely interact with normal matter. These particles could be their own antiparticles, meaning they annihilate each other when they meet, releasing energy. If these dark-matter particles exist, they could get captured by a planet's gravity and unleash energy that could warm that world. Larger, rocky "super-Earths" in regions with high densities of slow-moving dark matter could be warmed enough to keep liquid water on their surfaces, even in the absence of additional energy from starlight or other sources. The density of dark matter is expected to be up to thousands of times greater in the innermost regions of the Milky Way and the cores of dwarf spheroidal galax-

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ies than in our solar system. Scientists surmise that on these planets, dark matter rather than light may make it possible for life to develop and survive. Dark matter could keep surfaces warm for trillions of years. However, the scenario lies in the more optimistic end of models on how dark matter behaves. And current planet-hunting missions focus on worlds that starlight can help detect. Dark-matter-fueled planets not only might lie far from stars, but aren't very hot, making them hard to see.

A huge, ultra-bright powerful star explosion in late March left astronomers puzzled over how it happened. The explosion may have been the death cry of a star as it was ripped apart by a black hole. High-energy radiation continues to brighten and fade from the blast's location, 3.8 billion light-years away in Draco. Astronomers have never witnessed an explosion so bright, long-lasting and variable. The explosion looks like a gamma-ray burst, but the flaring emissions from these events never last more than a few hours. Milky Way objects can produce repeated bursts, but they're thousands to millions of times less powerful than the recent explosion. After the discovery by Swift, a Hubble image pinpointed the exact source of the blast, the center of a small galaxy. Astronomers used Chandra to make a four-hour exposure of the puzzling source. The explosion likely arose when a star wandered too close to its galaxy's central black hole. Intense tidal forces probably tore the star apart, and infalling gas continues to stream toward the black hole. According to this model, the spinning black hole formed an outflowing jet, which is blasting X-rays and gamma rays in our direction.

Astronomers have taken the pulse of red giants by measuring their starquakes, which run so deep they can reach a star's core. This can help scientists separate types of red giants that would otherwise look virtually identical, which could shed light on our Sun's future and the galaxy's past. Violent starquakes generate sound waves, which zip through stars and back to their surfaces. The way these sound waves interact with other waves fluctuating on a star can alter its brightness regularly, changes scientists can observe and which are sensitive to the structure of the cores of the stars. Researchers, observing 400 red giants, discovered hydrogen-burning stars demonstrated a range of sequences of a kind of gravity-linked vibration that differed from each other in the time they took to complete by up to 50 seconds, while helium-burning ones showed differences of 100 to 300 seconds. The cores of these latter stars are much hotter and less dense, meaning sound travels slower through them.

NASA is seeking partners to help achieve its strategic goals for education, including informal education at planetariums, museums and science centers. The agency is committed to sharing the excitement of NASA's space-based missions and inspiring students of all ages to pursue studies in science, technology, engineering and math. NASA seeks unfunded partnerships with organizations to engage new or broader audiences on a national scale. The agency will work collaboratively to leverage partners' unique resources. Proposals will be accepted through December 31. Info: http://www.nasa.gov/offices/education/about/NASA_Seeks_Collaborators.html.

NASA unveiled a flood of photos showing millions of galaxies, stars and asteroids photographed by a prolific sky-mapping telescope that ended its mission this year. The agency released more than half of the 2.7 million images taken by its Wide-field Infrared Survey Explorer (WISE) telescope during its mission to map the entire sky. WISE spent 14 months shooting in infrared. It hunted for asteroids and comets, as well as more distant objects revealed by their faint glow. Observations have been used since they first came in, but this is the first time much of the data have been made public. Scientists expect broadened exposure of the photos will enable a new wave of discoveries. While circling the Earth in polar orbit, WISE captured images of faraway galaxies and nearby asteroids. It surveyed the sky 1 1/2 times in four different wavelengths of light. WISE discovered 20 comets, more than 33,000 asteroids between Mars and Jupiter, and 133 NEOs. ■

Contacting the AAA

General club matters: president@aaa.org. Membership business, such as dues and change of address: members@aaa.org. *Eyepiece:* editor@aaa.org. Lectures: lectures@aaa.org. Classes: classes@aaa.org. Seminar: seminar@aaa.org. Observing: president@aaa.org. Please visit us on the web at www.aaa.org. ■

Events on the Horizon
May 2011

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

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

Tuesdays May 3, 10, 17, 23 and 30
Observing on the High Line, Manhattan, P, T, C
Enter at 14th Street. Next dates: Tuesdays in June.

Thursday, May 5, 6:30-8:30 p. m.
Recent Advances in Astronomy Seminar, M
NYU, 726 Broadway, 6th floor conference room.
Next date: TBA.

Friday, May 6, 6:15 p. m.
AAA lecture, FREE, P
David J. Thompson, a deputy project scientist for the Fermi Gamma-ray Space Telescope at NASA's Goddard Space Flight Center in Greenbelt, Md., will close the AAA's 2010-11 lecture series when he speaks on "Exploring the Extreme Universe with the Fermi Gamma -ray Space Telescope" in the Kaufmann Theater of the AMNH.

Saturday, May 7, 8 to 10 p. m.
Special observing session at Fort Tilden in the Rockaways, P, T, C
Location to be determined. Call Rich Rosenberg at 718-522-5014 for details.

Saturday, May 7, 7:30-11 p. m.
Observing at Great Kills Gateway National Park, Staten Island, P, T, C. Next date: June 4.

Monday, May 9, 7:30 p. m.
Hayden Planetarium lecture, P, AMNH
In "Physics of the Future," the title of his new book, CUNY theoretical physics professor Michio Kaku will discuss his forecasts of scientific leaps in the next century, including an elevator to space.

Wednesday, May 11, 6:30 p. m., M, HQ
Special meeting of AAA board to decide whether to increase dues to $35, and whether to pass bylaws revisions. If either passes, it will be voted on by the full membership at the annual meeting Wednesday, May 18.

Fridays, May 13 and 27, 8-11 p. m.
Observing at Inwood Hill Park, Manhattan, P, T, C
Next dates: June 10 and 24.

Friday, May 13, 8-10 p. m.
Observing at Floyd Bennett Field, Brooklyn, P, T, C
Next date: June 10.

Wednesday, May 18, 6:30 p. m.
AAA annual meeting, M, HQ
Buffet dinner at 6:30, business meeting at 7:30. All members are invited to attend. See back page for details.

Wednesday, May 25, May 25, 8-10 p. m.
Observing at Brooklyn Heights Promenade, P, T, C
At end of Montague Street. Next date: TBA.

Saturday May 28, 10-noon
Solar observing at Central Park, P, T, C
At the Conservatory Water. Next date: June 25.

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face and computer interactive exhibits.

Visitors will see authentic equipment and models of historic spacecraft. They will learn about robotic missions currently headed deeper into our solar system and what they might reveal. There will be insight on why geologists are interested in specimens from moons and planets, and what can be learned from them.

Displays will show possible missions of the future: returning humans to the Moon, landing on and deflecting a potentially deadly asteroid, or traveling to Mars and perhaps establishing colonies there. ■

AAA Annual Meeting May 18
All Members Are Welcome!

In accordance with the AAA bylaws, the annual meeting will be held Wednesday, May 18 at headquarters, Downtown Community Center, 120 Warren St. 6:30 p. m.: social gathering with buffet. 7:30 p. m.: annual meeting.

The 7:30 p. m. meeting will include elections to fill vacancies on the AAA board of directors. Nominations, besides those made by the nominating committee, may be presented to the AAA president or to the recording secretary no later than seven days before the annual meeting. Each such additional nomination requires the signatures of at least 18 AAA members.

MESSENGER continued from page 6

Finally, and most tantalizing, will be the identification of strange materials at Mercury's poles. At the poles, some craters are so deep they're in permanent shadow. Radar studies have shown highly reflective material in the craters that may be water ice. The extremes of Mercury are so great that the noontime solar side can reach 800 degrees, but the polar craters can hit a few hundred degrees below zero. The night side can plummet to -300.

Why study Mercury? Arguably, no one will ever go there, and there's little chance life ever existed. Ebel's response, backed by NASA scientists on a conference call, was that this little known world holds clues to the origin of terrestrial planets. But I prefer to think scientists feel akin to George Mallory about why climb Everest: "Because it is there."

Studying Mercury is pure exploration, as the NASA team stated in the webcast, and it represents a technological and scientific challenge to tease the secrets out of this harsh world. On this night, the risks paid off, and the long trek was over. Now begins the science.

On March 29, MESSENGER sent its first pictures from orbit, including surfaces that hadn't been imaged. Looking like a shattered windshield, the great crater Debussy displayed long rays stretching into the night.

NASA's website for the mission is http://messenger.jhuapl.edu/ ■

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