Black Hole

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Opportunity Surpasses 20 Kilometers

(NASA/JPL) NASA’s Mars Exploration Rover Opportunity recently surpassed 20 kilometers (12.43 miles) of total driving since it landed on Mars over 74 months ago.

The drive taking the rover past that total covered 67 meters (220 feet) southward as part of the rover's long-term trek toward Endeavour Crater to the southeast. It was on the 2,191st Martian day, or sol, of the mission and brought Opportunity's total odometry to 20.0433 kilometers. To reach Endeavour, the healthy but aging rover will need to drive about 12 kilometers (7.5 miles) farther.

Opportunity's mission on Mars was originally planned to last for three months with a driving-distance goal of 600 meters (less than half a mile).

Since landing, Opportunity has examined a series of craters on the plain of Meridiani, and the journey so far has covered a portion of the plain with negligible tilt. Now, the rover is approaching a portion tilting slightly southward. Recent images toward the southwest show the rim of a crater named Bopolu, about 65 kilometers (40 miles) away.

Meanwhile, Spirit, Opportunity's twin, is continuing minimal operations due to declining solar energy with the approach of winter in Mars' southern hemisphere. Spirit has been communicating on schedule once per week. It is expected to drop to a low-power hibernation mode soon that could prevent communications for weeks at a time during the next several months.

NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, manages the Mars Exploration Rover Project for the NASA Science Mission Directorate, Washington.

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Editor: Dr. Dale Etheridge, CSN Planetarium Director • Graphic Design: Denise MacRae
Circulation Manager: Pam Maher
Spitzer Unearths Primitive Black Holes

(NASA/SSC) Astronomers have come across what appear to be two of the earliest and most primitive supermassive black holes known. The discovery, based largely on observations from NASA’s Spitzer Space Telescope, will provide a better understanding of the roots of our universe, and how the very first black holes, galaxies and stars came to be.

"We have found what are likely first-generation quasars, born in a dust-free medium and at the earliest stages of evolution," said Linhua Jiang of the University of Arizona, Tucson. Jiang is the lead author of a paper announcing the findings in the March 18 issue of Nature.

Black holes are beastly distortions of space and time. The most massive and active ones lurk at the cores of galaxies, and are usually surrounded by doughnut-shaped structures of dust and gas that feed and sustain the growing black holes. These hungry, supermassive black holes are called quasars.

As grimy and unkempt as our present-day universe is today, scientists believe the very early universe didn’t have any dust, which tells them that the most primitive quasars should also be dust-free. But nobody had seen such immaculate quasars, until now. Spitzer has identified two, the smallest on record, about 13 billion light-years away from Earth.

The quasars, called J0005-0006 and J0303-0019, were first unveiled in visible light using data from the Sloan Digital Sky Survey. That discovery team, which included Jiang, was led by Xiaohui Fan, a coauthor of the recent paper at the University of Arizona. NASA’s Chandra X-ray Observatory had also observed X-rays from one of the objects. X-rays, ultraviolet and optical light stream out from quasars as the gas surrounding them is swallowed.

"Quasars emit an enormous amount of light, making them detectable literally at the edge of the observable universe," said Fan.

When Jiang and his colleagues set out to observe J0005-0006 & J0303-0019 with Spitzer between 2006 and 2009, their targets didn’t stand out much from the usual quasar bunch. Spitzer measured infrared light from the objects along with 19 others, all belonging to a class of the most distant quasars known. Each quasar is anchored by a supermassive black hole weighing more than 100 million suns.

Of the 21 quasars, J0005-0006 and J0303-0019 lacked characteristic signatures of hot dust, the Spitzer data showed. Spitzer’s infrared sight makes the space telescope ideally suited
to detect the warm glow of dust that has been heated by feeding black holes.

"We think these early black holes are forming around the time when the dust was first forming in the universe, less than one billion years after the Big Bang," said Fan. "The primordial universe did not contain any molecules that could coagulate to form dust. The elements necessary for this process were produced and pumped into the universe later by stars."

The astronomers also observed that the amount of hot dust in a quasar goes up with the mass of its black hole. As a black hole grows, dust has more time to materialize around it. The black holes at the cores of J0005-0006 and J0303-0019 have the smallest measured masses known in the early universe, indicating they are particularly young, and at a stage when dust has not yet formed around them.

Other authors include W. N. Brandt of Pennsylvania State University, University Park; Chris L. Carilli of the National Radio Astronomy Observatory, Socorro, NM; Eiichi Egami of the University of Arizona; Dean C. Hines of the Space Science Institute, Boulder, Colo.; Jaron D. Kurk of the Max Planck Institute for Extraterrestrial Physics, Germany; Gordon T. Richards of Drexel University, Philadelphia, Pa.; Yue Shen of the Harvard Smithsonian Center for Astrophysics, Cambridge, Mass.; Michael A. Strauss of Princeton, NJ; Marianne Vestergaard of the University of Arizona and Niels Bohr Institute in Denmark; and Fabian Walter of the Max Planck Institute for Astronomy, Germany. Fan and Kurk were based in part at the Max Planck Institute for Astronomy when this research was conducted.

The Spitzer observations were made before the telescope ran out of its liquid coolant in May 2009, beginning its "warm" mission.

NASA's Jet Propulsion Laboratory, Pasadena, Calif., manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at the California Institute of Technology. Caltech manages JPL for NASA.

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Mars Rover Examines Odd Material at Small, Young Crater

(NASA/JPL) Weird coatings on rocks beside a young Martian crater remain puzzling after a preliminary look at data from examination of the site by NASA's Opportunity rover.

The rover spent six weeks investigating the crater called "Concepción" before resuming its long journey in March. The crater is about 33 feet in diameter. Dark rays extending from it, as seen from orbit, flagged it in advance as a target of interest because the rays suggest the crater is young.

The rocks ejected outward from the impact that dug Concepción are chunks of the same type of bedrock Opportunity has seen at hundreds of locations since landing in January 2004: soft, sulfate-rich sandstone holding harder peppercorn-sized dark spheres like berries in a muffin. The little spheres, rich in iron, gained the nickname "blueberries."

This image shows NASA's Mars Exploration Rover Opportunity perched on the edge of "Concepción" crater in Meridiani Planum, Mars. The image was acquired by the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter on February 13, 2010, during the 2,153rd Martian day, or sol, of Opportunity's mission on Mars.
"It was clear from the images that Opportunity took on the approach to Concepción that there was strange stuff on lots of the rocks near the crater," said Steve Squyres of Cornell University, Ithaca, NY, principal investigator for Opportunity and its twin rover, Spirit. "There’s dark, grayish material coating faces of the rocks and filling fractures in them. At least part of it is composed of blueberries jammed together as close as you could pack them. We’ve never seen anything like this before."

Opportunity used tools on its robotic arm to examine this unusual material on a rock called "Chocolate Hills." In some places, the layer of closely packed spheres lies between thinner, smoother layers. "It looks like a blueberry sandwich," said Matt Golombek, a rover science-team member at NASA's Jet Propulsion Laboratory, Pasadena, Calif.

Initial analysis of the coating’s composition does not show any obvious component from whatever space rock hit Mars to dig the crater, but that is not a surprise, Golombek said. "The impact is so fast, most of the impactor vaporizes," he said. "Thin films of melt get thrown out, but typically the composition of the melt is the stuff that the impactor hit, rather than the impactor material."

The composition Opportunity found for the dark coating material fits at least two hypotheses being evaluated, and possibly others. One is that the material resulted from partial melting of blueberry-containing sandstone from the energy of the impact. Another is that it formed from filling of fractures in this type of rock before the impact occurred.

"It's possible that when you melt this rock, the sandstone melts before the blueberries do, leaving intact blueberries as part of a melt layer," Squyres said. "As an alternative,
we know that this type of rock has fractures and that the sandstone can dissolve. Long ago, water flowing through fractures could have dissolved the sandstone and liberated blueberries that fell down into the fracture and packed together. In this hypothesis, the impact that excavated the crater did not play a role in forming this material, but split rocks along fractures so the material is exposed on the exterior like a coating."

Golombek said, "One consideration that jumps out is that we’ve been driving around this part of Mars for six years and never seen this stuff before, then we get to this young crater and it’s coating rocks all around the crater. Sure looks like there's a connection, but it could just be a coincidence."

The observation that the rocks thrown from the crater have not yet eroded away much is evidence that the crater is young, confirming the suggestion from the dark rays. Squyres said, "We’re not ready to attach a number to it, but this is really young. It is the youngest crater we’ve ever seen with Opportunity and probably the youngest either rover has seen."

One question Opportunity’s visit did answer was about the dark rays: "We wondered before getting to Concepción why the rays are dark," Golombek said. "We found out that the rays are areas with blocks of light-toned sandstone ejected from the crater. They look dark from orbit because of the shadows that the blocks are casting when the orbital images are taken in mid-afternoon."

Since departing Concepción on March 9, Opportunity has driven 2,014 feet farther along the route to its long-term destination at Endeavour Crater, about 12 miles in diameter and still at a drive distance of more than 7 miles.

Squyres said, "We’re on the road again. We have a healthy rover and we have enough power for substantial drives. We want to get to Endeavour with a healthy rover. It takes a compelling target for us to stop and study. And Concepción was a compelling target."
Laboratory, Pasadena, Calif. She is a rover driver, a senior member of JPL’s Artificial Intelligence Group and leader of development for this new software system.

The new system is called Autonomous Exploration for Gathering Increased Science, or AEGIS. Without it, follow-up observations depend on first transmitting the post-drive navigation camera images to Earth for ground operators to check for targets of interest to examine on a later day. Because of time and data-volume constraints, the rover team may opt to drive the rover again before potential targets are identified or before examining targets that aren’t highest priority.

The first images taken by a Mars rover choosing its own target show a rock about the size of a football, tan in color and layered in texture. It appears to be one of the rocks tossed outward onto the surface when an impact dug a nearby crater. Opportunity pointed its panoramic camera at this unnamed rock after analyzing a wider-angle photo taken by the rover’s navigation camera at the end of a drive on March 4. Opportunity decided that this particular rock, out of more than 50 in the navigation camera photo, best met the criteria that researchers had set for a target of interest: large and dark.

"It found exactly the target we would want it to find," Estlin said. "This checkout went just as we had planned, thanks to many people's work, but it’s still amazing to see Opportunity performing a new autonomous activity after more than six years on Mars."

Opportunity can use the new software at stopping points along a single day’s drive or at the end of the day’s drive. This enables it to identify and examine targets of interest that might otherwise be missed.

"We spent years developing this capability on research rovers in the Mars Yard here at JPL," said Estlin. "Six years ago, we never expected that we would get a chance to use it on Opportunity."

The developers anticipate that the software will be useful for narrower field-of-view instruments on future rovers.
Other upgrades to software on *Opportunity* and its twin, *Spirit*, since the rovers’ first year on Mars have improved other capabilities. These include choosing a route around obstacles and calculating how far to reach out a rover’s arm to touch a rock. In 2007, both rovers gained the know-how to examine sets of sky images to determine which ones show clouds or dust devils, and then to transmit only the selected images. The newest software upload takes that a step further, enabling *Opportunity* to make decisions about acquiring new observations.

The AEGIS software lets scientists change the criteria it used for choosing potential targets. In some environments, rocks that are dark and angular could be higher-priority targets than rocks that are light and rounded, for example.

This new software system has been developed with assistance from NASA’s Mars Exploration Rover Project and with funding from the New Millennium Program, the Mars Technology Program, the JPL Interplanetary Network Development Program, and the Intelligent Systems Program. The New Millennium Program tests advanced technology in space flight. JPL, a division of the California Institute of Technology in Pasadena, manages the Mars Exploration Rover Project for the NASA Science Mission Directorate, Washington.

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The Astronomy Store features items for sale that are of interest to the patrons of The Planetarium. We carry a wide variety of novelties, toys and observing aids with a space or astronomical theme. When patrons obtain their tickets to planetarium shows, they can also purchase a variety of astronomically oriented items. *Friends of The Planetarium* receive a 10% discount.

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**Ashes to Ashes, Dust to Dust**

(NASA/SSC) A new image (at left) from NASA’s *Chandra* and *Spitzer* space telescopes shows the dusty remains of a collapsed star. The dust is flying past and engulfing a nearby family of stars.

"Scientists think the stars in the image are part of a stellar cluster in which a supernova exploded," said Tea Temin of the Harvard-Smithsonian Center for Astrophysics, Cambridge, Mass., who led the study. "The material ejected in the explosion is now blowing past these stars at high velocities."

It shows the *Chandra X-ray Observatory* data in blue, and data from the *Spitzer Space Telescope* in green (shorter wavelength) and red-yellow (longer). The white source near the center of the image is a dense, rapidly rotating neutron star, or pulsar, left behind after a core-collapse supernova explosion. The pulsar generates a wind of high-energy particles, seen in the *Chandra* data, that
expands into the surrounding environment, illuminating the material ejected in the supernova explosion.

The infrared shell that surrounds the pulsar wind is made up of gas and dust that condensed out of debris from the supernova. As the cold dust expands into the surroundings, it is heated and lit up by the stars in the cluster so that it is observable in infrared. The dust closest to the stars is the hottest and is seen glowing in yellow in the image. Some of the dust is also being heated by the expanding pulsar wind as it overtakes the material in the shell.

The unique environment into which this supernova exploded makes it possible for astronomers to observe the condensed dust from the supernova that is usually too cold to emit in infrared. Without the presence of the stellar cluster, it would not be possible to observe this dust until it becomes energized and heated by a shock wave from the supernova. However, the very action of such shock heating would destroy many of the smaller dust particles. In G54.1+0.3, astronomers are observing pristine dust before any such destruction.

G54.1+0.3 provides an exciting opportunity for astronomers to study the freshly formed supernova dust before it becomes altered and destroyed by shocks. The nature and quantity of dust produced in supernova explosions is a long-standing mystery, and G54.1+0.3 supplies an important piece to the puzzle.


The Spitzer observations were made before the telescope ran out of its coolant in May 2009 and began its “warm” mission. NASA’s Jet Propulsion Laboratory manages Spitzer for NASA’s Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at the California Institute of Technology in Pasadena. Caltech manages JPL for NASA.

Small Companion to Brown Dwarf Challenges Simple Definition

(NASA/STScI) As our telescopes grow more powerful, astronomers are uncovering objects that defy conventional wisdom. The latest example is the discovery of a planet-like object circling a brown dwarf. It’s the right size for a planet, estimated to be 5-10 times the mass of Jupiter. But the object formed in less than 1 million years, the approximate age of the brown dwarf, and much faster than the predicted time it takes to build planets according to some theories.

Kamen Todorov of Penn State University and co-investigators used the keen eyesight of the Hubble Space Telescope and the Gemini Observatory to directly image the companion of the brown dwarf, which was uncovered in a survey of 32 young brown dwarfs in the Taurus star-forming region. Brown dwarfs are objects that typically are tens of times the mass of Jupiter and are too small to sustain nuclear fusion to shine as stars do.

The mystery object orbits the nearby brown dwarf at a separation of approximately 2.25
billion miles (between the distances of Saturn and Uranus from the Sun). The team’s research is being published in an upcoming issue of *The Astrophysical Journal*.

There has been a lot of discussion in the context of the Pluto debate over how small an object can be and still be called a planet. This new observation addresses the question at the other end of the size spectrum: How small can an object be and still be a brown dwarf rather than a planet? This new companion is within the range of masses observed for planets around stars, less than 15 Jupiter masses. But should it be called a planet? The answer is strongly

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connected to the mechanism by which the companion most likely formed.

There are three possible formation scenarios: Dust in a circumstellar disk slowly agglomerates to form a rocky planet 10 times larger than Earth, which then accumulates a large gaseous envelope; a lump of gas in the disk quickly collapses to form an object the size of a gas giant planet; or, rather than forming in a disk, a companion forms directly from the collapse of the vast cloud of gas and dust in the same manner as a star (or brown dwarf).

If the last scenario is correct, then this discovery demonstrates that planetary-mass bodies can be made through the same mechanism that builds stars. This is the likely solution because the companion is too young to have formed by the first scenario, which is very slow. The second mechanism occurs rapidly, but the disk around the central brown dwarf probably did not contain enough material to make an object with a mass of 5-10 Jupiter masses.

"The most interesting implication of this result is that it shows that the process that makes binary stars extends all the way down to planetary masses. So it appears that nature is able to make planetary-mass companions through two very different mechanisms," says team member Kevin Luhman of the Center for Exoplanets and Habitable Worlds at Penn State University. If the mystery companion formed through cloud collapse and fragmentation, as stellar binary systems do, then it is not a planet by definition because planets build up inside disks.

The mass of the companion is estimated by comparing its brightness to the luminosities predicted by theoretical evolutionary models for objects at various masses for an age of one million years.

Further supporting evidence comes from the presence of a very nearby binary system that contains a small red star and a brown dwarf. Luhman thinks that all four objects may have formed in the same cloud collapse, making this in actuality a quadruple system. "The configuration closely resembles quadruple star systems, suggesting that all of its components formed like stars," says Luhman.
Month in History

June

1: Commander John Ross of the Royal Navy located the north magnetic pole in 1831.
2: Surveyor 1 was the first U.S. spacecraft to land softly on the moon in 1966.
3: The first U.S. space walk was accomplished by astronaut Ed White on Gemini 4 1965. White was outside the Gemini capsule for 22 minutes.
6: When Soyuz 11 was launched into earth orbit in 1971, it became the first spacecraft to carry a human crew to an orbiting space station (Salyut 1).
8: The first free flight of the hypersonic research craft X-15 in 1957. The craft was dropped from under the wing of a B-52 for an unpowered glide test.
9: In 1931, the American Robert Goddard patented the first rocket powered aircraft design.
11: In 1985, the two Soviet Vega spacecraft were the first to use balloons in the investigation of the atmosphere of another world during a flyby of Venus on their way to Comet Halley.
13: Pioneer 10 launched March 2, 1972, became the first man-made object to cross the orbit of Pluto, then considered the most distant planet, in 1983.
16: Valentina Tereshkova, aboard Vostok 6, became the first woman in space in 1963. She is also the only woman to solo in space.
18: Sally Ride became the first American woman in space in 1983, twenty years after Valentina Tereshkova. See June 16.
20: The first liquid fueled rocket plane, the Heinkel He-176, flew in Germany in 1939.
22: Charon, the moon of Pluto, was discovered by James Christy of the U. S. Naval Observatory in 1978.
23: The three man crew of Soyuz 11, the first crew to successfully visit a space station in orbit (Salyut 1), died during reentry due to a hatch failure that resulted in a loss of cabin pressure. See June 6.
25: Hermann Oberth, who was instrumental in the development of theories and hardware for rocket flight in the 1920’s and 30’s was born on this date in 1894.
26: Charles Messier, famous French comet seeker and creator of the Messier Catalog, was born on this date in 1730. He helped to establish the tradition of naming comets for their discoverers.
27: The X-15 rocket plane set an atmospheric speed record of 6,606 km/hr (4,105 mi/hr) in 1962.
29: George Ellery Hale, the moving force behind the development of the then largest telescope in the world at four different times, was born in 1868. The five meter telescope on Palomar Mountain is named in his honor.

Give a Star

A popular service of The CSN Planetarium lets you dedicate a star to a loved one. For a donation of $35, we will provide an attractive certificate that proclaims your dedication of the star of your choice to any other person. The certificate will have a chart of the constellation containing the star and complete information about the star. A donation of $100 will give you an exclusive dedication. Call 651-4138 or 651-4505 for further information.
All times are Pacific Daylight Time. Rise and set times are for the astronomical horizon at Las Vegas or Reno as noted.

### The Planets

**Mercury.** Mercury is low in the east shortly before sunrise for the first part of the month. Superior conjunction on the far side of the sun occurs on June 28.

**Venus.** Venus is appears low in the western sky after sunset. It is setting about three hours after the sun. Look for the waxing crescent moon below Venus on the evening of June 14.

**Mars.** Mars, in Leo, is in the southwest at sunset. It is about halfway between Venus and Saturn. Look for the waxing crescent moon to the left of Mars on the evening of June 17.

**Jupiter.** Jupiter, in Pisces, is rising in the east shortly after midnight. The waning crescent moon is to the left of Jupiter and Uranus on the morning of June 6.

**Saturn.** Saturn, in Virgo, is high in the southwest in the early evening. The waxing crescent moon will be below Saturn on the evening of June 18.

**Uranus.** Uranus, in Pisces, is low in the eastern sky just before sunrise. It is rising along with Jupiter. The two will be $\frac{1}{2}^\circ$ apart on June 6.

**Neptune.** Neptune, in Aquarius, is rising in the east at about midnight. The waning gibbous moon will rise to the left of Neptune shortly after midnight on the morning of June 4.

### Dwarf Planets

<table>
<thead>
<tr>
<th>Planet</th>
<th>Constellation</th>
<th>Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pluto</td>
<td>Sagittarius</td>
<td>1:25 am (36°)</td>
</tr>
<tr>
<td>Ceres</td>
<td>Sagittarius</td>
<td>12:59 am (29°)</td>
</tr>
<tr>
<td>Eris</td>
<td>Cetus</td>
<td>8:47 am (50°)</td>
</tr>
<tr>
<td>MakeMake</td>
<td>Coma Berenices</td>
<td>7:35 pm (82°)</td>
</tr>
<tr>
<td>Haumea</td>
<td>Boötes</td>
<td>8:44 pm (73°)</td>
</tr>
</tbody>
</table>

All Dwarf Planets require a telescope. Ceres is visible through most amateur telescopes. Pluto usually requires a telescope of at least 12" diameter. Dwarf planets beyond the orbit of Neptune can also be referred to as Plutoids. Eris ("EE-ris"), MakeMake (mah-keh-mah-keh) and Haumea, like most Plutoids, require a professional sized telescope. Transit times and altitudes (from Las Vegas) are when the object is at its highest in the southern sky. Each will appear slightly lower in the sky from Reno.

### The Moon

Each day the moon rises about one hour later than the day before. The New Moon (not visible) is in the direction of the sun and rises and sets with the sun. The first quarter moon rises at about noon and sets near midnight. The full moon is opposite the sun in the sky and rises at sunset and sets at sunrise. The last quarter moon rises near midnight and sets near noon. Perigee is when the moon is closest to the earth and apogee is when it is farthest. The distance varies by ±6% from the average.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Moon</td>
<td>May 27</td>
<td>4:07 pm pdt</td>
</tr>
<tr>
<td>Last quarter</td>
<td>Jun. 4</td>
<td>3:13 pm</td>
</tr>
<tr>
<td>New Moon</td>
<td>Jun. 12</td>
<td>4:15 am</td>
</tr>
<tr>
<td>First quarter</td>
<td>Jun. 18</td>
<td>9:29 pm</td>
</tr>
<tr>
<td>Full Moon</td>
<td>Jun. 26</td>
<td>4:30 am</td>
</tr>
<tr>
<td>Apogee</td>
<td>Jun. 3</td>
<td>9:52 am pdt</td>
</tr>
<tr>
<td>Perigee</td>
<td>Jun. 15</td>
<td>7:55 am</td>
</tr>
<tr>
<td>Apogee</td>
<td>July 1</td>
<td>3:13 am</td>
</tr>
</tbody>
</table>

There will be a partial eclipse of the moon on the morning of June 26. The eclipse maximum (54%) will occur at 4:38 am as the moon is setting in the west.
Summer Solstice

As the earth revolves around the sun, its north pole is tilted alternately towards and away from the sun. The date when the north pole is tilted most directly towards the sun is called the summer solstice. This year it occurs on June 21 at 4:28 am pdt.

Because of the 23½ degree tilt of the earth’s axis of rotation (here tilted away from the observer), the daily path of the sun varies during the year. In the summer, the sun rises north of east, climbs high in the southern sky at midday, and sets north of west. Days are long and nights are short. In the winter, when the north pole is tilted away from the sun, days are short and nights are long. The sun rises south of east, stays low in the southern sky at midday, and sets south of west.

On the summer solstice, the sun rises at its northernmost position along the eastern horizon and sets at its northernmost position along the western horizon. Many ancient civilizations used observation of this phenomenon to keep their calendars from drifting, and one of the more obvious things Stonehenge was built for was to keep calendars accurate.

The number of hours of daylight is greatest on the solstice, being 14½ hours for Las Vegas (about 15 hours for Reno). This also marks the shortest night of the year with only 9½ hours at Las Vegas (about 9 hours for Reno). If you notice the sunrise and sunset table on this page, you’ll find that solstice, though, is not the date of the earliest sunrise, nor of the latest sunset. The difference is caused by the solstice being measured with respect to the center of the sun and the rise and set times being measured from the upper limb of the sun.

The high angle of the noon sun increases the efficiency with which the sun heats the ground. Combined with long days and short nights, this is why the summer months are hot in our region. The opposite occurs in the winter, producing cold weather. The reason our hottest part of summer and coldest part of winter come some weeks after the solstices is that the temperature of the planet is somewhat buffered by the thermal lag of the surface, which takes a while to warm up in summer and cool down in winter.
In Las Vegas

**Extreme Planets**

**Black Holes**

**The Little Star That Could**

**Seasonal Stargazing**

In Reno

Please call 775-784-4811 or visit our web site at <http://planetarium.unr.edu/> for current schedule information about our features in SciDome™ and Skydome 8/70™

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