SkyWAAtch

. . . One Small Step

On July 20th, 1969, a human first set foot on the Moon. Pictured above is the first lunar footprint. It belongs to Neil Armstrong. On August 25th, 2012, Neil Armstrong passed away at the age of 82. It has been estimated that one billion people world-wide watched Armstrong's initial lunar trek. For so many, this footprint marks the initial step on a path to an inspiring future. It is a testament to a modest man, who will be remembered as an exceptional pilot, engineer, administrator and space-pioneer (his NASA biography).

Image Credit:Apollo 11 Crew, NASA

Events for September 2012

WAA Lectures

“Member Presentations Night”
Friday September 7th, 7:30pm
Miller Lecture Hall, Pace University
Pleasantville, NY

WAA members will showcase their astrophotos, equipment and other insights. Currently scheduled, Pat Mahon will present “A Letter from Galileo.” John Paladini will exhibit and describe his latest astronomical creation: the "Promoscope or Solar Prominence telescope.” Bob Kelly will present: "Photos from Here and There--From Canon to Cassini.” Josh Knight will speak on his "Stellafane Experience" and Larry Faltz will present "The Transit of Venus from Hawaii" Free and open to the public. Directions and Map.

More Upcoming Lectures
Miller Lecture Hall, Pace University
Pleasantville, NY

On Friday October 5th Mr. Al Witzgall will present on “The End of the World--But Don’t lose Any Sleep On It.” It will provide his response to the Mayan and other 2012 doomsday predictions. On Friday November 2nd our speaker will be Dr. Caleb Scharf, who is the Chairman of the Astrobiology Department at Columbia University. His talk will be entitled “Planets, Stars, Black Holes and the Quest for Our Cosmic Origins” and will elaborate on the subject of his latest book, *Gravity's Engines*. On December 7th, Jeffrey Jacobs will be showing his film “ A Sidewalk Astronomer,” followed by a Q&A. Lectures are free and open to the public.

Starway to Heaven

Saturday September 15th, Dusk
Meadow Picnic Area, Ward Pound Ridge Reservation, Cross River

This is our scheduled Starway to Heaven observing date for September, weather permitting. Free and open to the public. The scheduled rain/cloud date is September 22nd. Participants and guests should read and abide by our General Observing Guidelines and Disclaimer. Directions

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

New Members. . .

Satya Nitta - Cross River
Frank Moliterno - Mt. Vernon
Eric and Katherine Baumgartner - Redding
Erik Esposito - Bronxville
Tanay Bhandarkar - Cortlandt Manor
The Cerbone Family - Tarrytown
Joseph Esposito - New York

Renewing Members. . .

Michael & Ann Cefola - Scarsdale
Joe Geller - Hartsdale
Patricia Mahon - Yonkers
Ihor Szkolar - White Plains
John James - Sunnyside
Deidre Raver - Wappingers Falls

CALL FOR SUBMISSIONS

The ***SkyWaatch*** is always looking for contributions. Write an article or share your astrophotos, observing reports or book reviews with fellow WAA’ers. Material should be related to amateur astronomy or space science. Send the materials to the Newsletter.

WAA APPAREL

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

- **Caps, $10** (navy and khaki)
- **Short Sleeve Polos, $12** (navy).

Isaac Newton
Credit: Enoch Seeman, in 1726

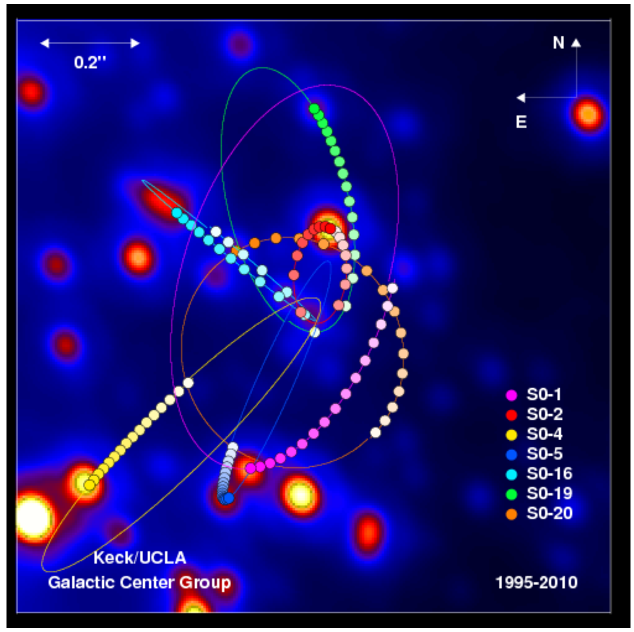
Articles and Photos

A Summer of Black Holes
by Larry Faltz

This summer I seem to have fallen into some black holes. Well, not physically, because then I wouldn't be here to write about them, but figuratively: four articles about black holes in a special section of the August 3rd issue of *Science*, an article in the August issue of *Scientific American* and Leonard Susskind's 2008 book *The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics*, the story of his 3-decades-long debate with Hawking about whether black holes cause information to be lost from the universe.

A black hole is the name (popularized by Princeton physicist John Archibald Wheeler) given to an object, more formally a region in spacetime, whose gravitational field, the curvature of space surrounding the object's mass, exceeds the escape velocity of light. While we think of this phenomenon as a consequence of Einstein's General Theory of Relativity, the idea was first suggested in 1783 by British geologist John Michell, working out the algebra of Newtonian gravity, and it was even discussed in the first two editions of Laplace's *Exposition du Système du Monde* (1796). That presumably massless light could be influenced by gravity seemed illogical to 19th century physicists, and only with Einstein did that concept become established as a fundamental tenet of physics.

Within months after the publication of the General Theory, Karl Schwarzschild came up with a solution to Einstein's (very complex) field equations for a spherical non-rotating body. If the mass were large enough, the radius would collapse to zero, in other words, a singularity. Remarkably, this singularity has the entire mass of the original object at a single point with zero volume. This was hard for physicists to believe, and for decades there was a common expectation that some other force would counteract the gravitational collapse. One was never found (although recent advances in string theory suggest there is a minimum volume to space, so that zero volume cannot actually occur). Theoretical and observational advances during the remainder of the 20th century brought black holes from a charming mathematical curiosity to a physical reality and then to a fundamental place in stellar evolution and galactic dynamics. Proof of their existence was provided by observations from high-energy detectors in space as well as meticulous infrared observations of the orbits of stars near the center of the Milky Way by gigantic modern telescopes, the twin Keck telescopes in Hawaii foremost among them.



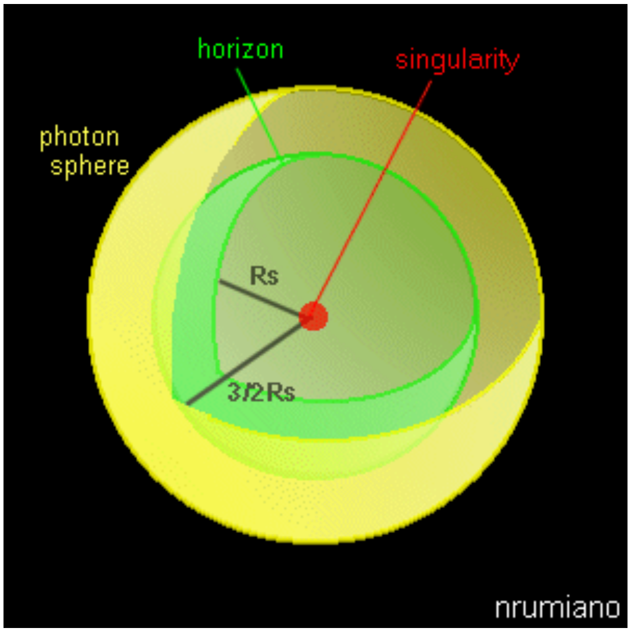
The dynamics of stellar orbits at the center of the Milky Way galaxy prove the existence of a black hole. A neat animation is also available.

Schwarzschild showed that the radius at which the escape velocity is equal to the speed of light (called of course the Schwarzschild radius, r_s) is given by the simple formula:

$$r_s = \frac{2Gm}{c^2}$$

where G is the gravitational constant, m is the mass and c of course is the speed of light.

I'm always fascinated when the solutions to very complex equations end up as very simple terms. $E=mc^2$ is of course the best example. In the case of the Schwarzschild radius, the equation allows us to easily calculate the size below which an object would need to shrink in order to become a black hole. For the Sun, which weighs about $2*10^{30}$ kilograms, the radius is 2.95 kilometers (a lot smaller than its current radius of 700,000 kilometers) and for the Earth a peanut-sized 9 millimeters.



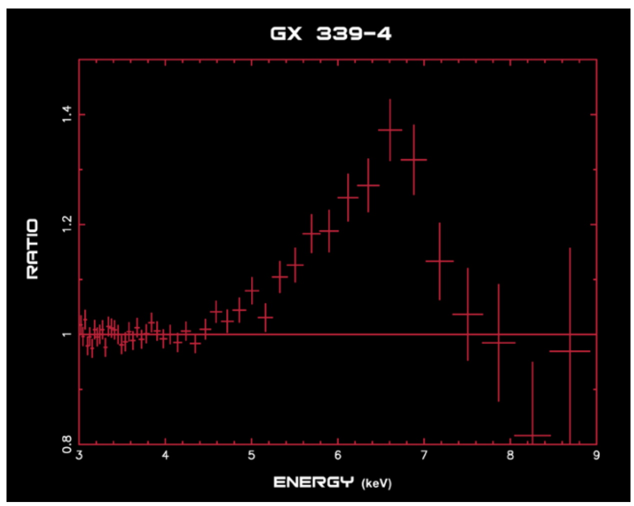
A simplified drawing of a black hole.

The singularity, with zero volume, has no surface, but the location in space at r_s forms a virtual spherical surface, the "event horizon", which is what we commonly refer to as the "black hole". This is not a physical object, although in many ways it behaves like a membrane, and it has some remarkable quantum and thermodynamic properties. No light can be emitted from this surface (it's black!) or from the region closer to the singularity. So we don't actually "see" the event horizon, nor can we say anything about the structure of the universe, at least from observations, inside this region of space.

Einstein's General Theory of Relativity showed that clocks slow down in a gravitational field, an effect that is actually compensated for in the Global Positioning Satellite system. Since orbiting satellites experience less gravity than the surface of the earth, their clocks run faster than those on the ground. If we were to observe an object falling into a black hole, as gravity increased its clock would run slower and slower and its radiation would become increasingly red-shifted. At the event horizon, the clocks are infinitely slow. It would take an infinite amount of time for the object to cross the event horizon. We would see its mass smeared out on the event horizon. However, General Relativity also says that if you were to fall into a black hole, from your perspective you would not notice the slowing of the clock or the smearing. Everything would appear just fine as you crossed r_s and headed for the singularity (of course, there would be no way for you to tell anyone about it). This duality is one of the remarkable consequences of relativity. It's one of the reasons why it's "relative".

There are many other interesting relativistic consequences of gravitational collapse. For example, we can't really speak about the "space" inside the event horizon. What happens there is that space and time actually exchange places. We don't really have various "places" inside the horizon, we actually have various "times". Remember that in relativity there is no separate space and time, but spacetime. A number of excellent web sites patiently provide (better) explanations in relatively understandable layman's language. One I like is Einstein On-Line, provided by the Max Planck Institute for Gravitational Physics in Germany. Another way of trying to understand the geometry of spacetime is through conformal diagrams, also known as Penrose diagrams after Oxford's Sir Roger Penrose, who invented them in the 1950's.

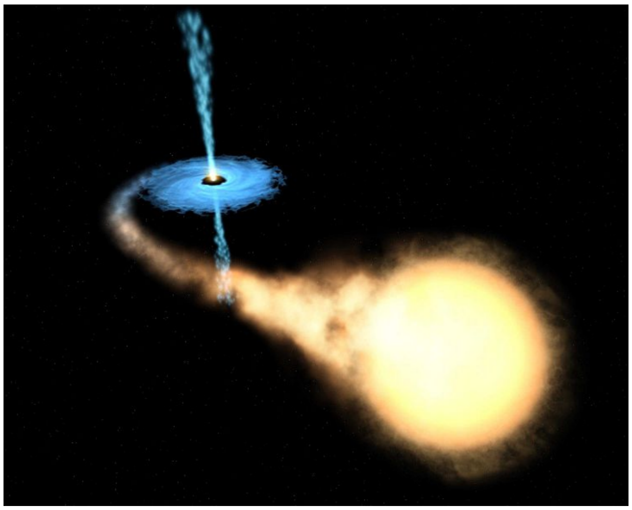
Black holes have fascinating origins, properties and consequences. They lie at the intersection of the three great paradigms of modern physics: relativity, quantum mechanics, and the Second Law of Thermodynamics. The eventual union of quantum mechanics and relativity in a quantum "theory of everything" will likely be worked out in part by comparing and uniting how each describes the properties of black holes.



The X-ray spectrum of GX 339-4, showing a broad, gravitationally red-shifted peak of X-rays emitted from matter in the accretion disk of this spinning black hole (Chandra).

At $1.5r_s$ we find the radius at which the orbit (not the escape velocity) of a stable object equals the speed of light. This is called the "photon sphere". What's interesting about this distance is that it's the point at which space is curved enough that an observer would perceive the surface of the black hole as a plane stretching off to infinity.

Surrounding the event horizon and extending outward is a dense ring of hot, viscous, rapidly rotating matter that emits X-rays. The first black hole candidate, Cygnus X-1, was found by a rocket-borne X-ray detector in 1964. It has an enormous X-ray flux and is thought to be a black hole weighing 14.8 solar masses with a Schwarzschild radius of 26 kilometers.



Artist's conception of a binary X-ray source like Cygnus X-1.

X-rays are emitted from matter at high temperature. In high-gravitation objects, the dense ring of orbiting matter is heated by friction. In most cases, the matter is supplied by a binary companion. The high mass component of an X-ray binary can be a neutron star, but the most intense emitters are black holes.

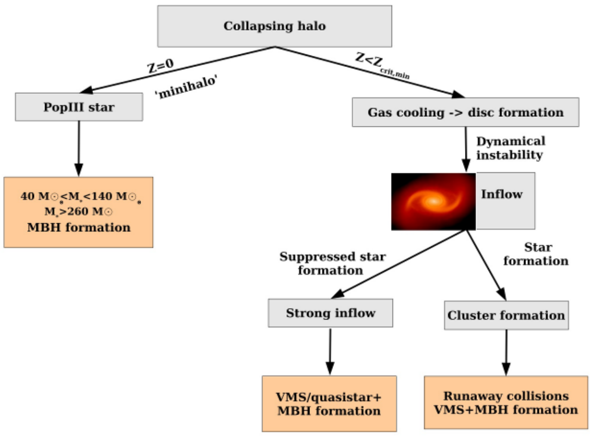
The rapidly rotating accretion disk can also create a powerful magnet along the axis of rotation. This results in emission along the axis of jets of charged particles near the speed of light. Many such jets have now been detected, the most famous one being the jet of the M87 galaxy.

The balance between gravity and heat keeps stars from collapsing. As stellar fuel is used up, the outflowing heat energy is unable to counterbalance gravitational contraction. When stars below the Chandrasekar limit of 1.44 solar masses consume enough of their nuclear fuel, they blow off their outer shells, forming a planetary nebula. The remaining stellar mass no longer undergoes fusion. The inward pull of gravity is resisted by "electron degeneracy pressure", a consequence of the Pauli exclusion principle that does not allow two fermions (particles with half-integer spins such as electrons and quarks) from having the same quantum state. The matter inside of white dwarfs is still atomic matter, but maximally compressed. Stars between 1.44 and around 8 solar masses have enough gravity to contract further, becoming neutron stars, further gravitational collapse again resisted by quantum degeneracy pressure, but this time the matter is made of pure neutrons (which are also fermions subject to the exclusion principle). For stars larger than 8 solar masses there is no mechanism to stop gravitational contraction. As their radius decreases, the gravitational force and the curvature of space increases. The higher the gravitational force, the higher the escape velocity of light. When the collapsing object gets smaller than its Schwarzschild radius, the body is a black hole.

There are probably millions of stellar-mass black holes in our galaxy alone, resulting from the collapse of massive stars formed early in its life, or from a companion star in a close binary adding enough mass to a white dwarf or neutron star to tip it over the collapse limit. The physics of stellar mass black holes is the subject of an interesting paper by Fender and Belloni in the August 3rd issue of *Science*. They are particular focused on describing how the object's X-ray signal varies in response to events that take place in the accretion disk when matter from the companion star falls into it.

M87's jet (Hubble).

At the center of most, if not all galaxies, are massive or supermassive black holes. They weigh from millions to billions of solar masses. The formation of these objects is still an unsettled question, although it is generally agreed that they formed early in the evolution of the universe, perhaps with the participation of large clumps of dark matter acting as a gravitational catalyst for galactic gas. Whether they can form directly or require the merging of many stellar-mass black holes (or both) is not clear. We see them now as active galactic nuclei and quasars with large red shifts. Another paper in the August 3rd *Science*, by Marta Volonteri of the University of Michigan and Institut d'Astrophysique de Paris, reviews the formation of massive black holes. This article followed a more technical review that she published in the spring.



Possible formation of massive black holes (MBH) in early galaxies (from Volonteri, M, Formation of Supermassive Black Holes, arXiv: 1003.4404v1.

Scientific American's August 2012 issue featured an article "The Black Hole in the Heart of the Milky Way" by Caleb Scharf, adapted from his recent book *Gravity's Engines*. Scharf is the Director of Astrobiology at the Columbia Astrophysics Laboratory. Scharf details the influence that the 4-million solar mass black hole at the center of the Milky Way has had on the distribution of matter and energy in our galaxy, subsequent galactic evolution and even the formation of life. I'll leave the details to Dr. Scharf himself: he'll be the speaker at WAA's November 2nd meeting at Pace this fall.

Two other commentaries in *Science* discuss some theoretical aspects of black hole physics. The first is "Classical Black Holes: The Non-Linear Dynamics of Curved Spacetime" by Kip Thorne, one of the world's leading experts on gravitation and relativity. Thorne discusses in non-mathematical terms the tidal forces near black holes and how gravitational waves form when rotating black holes merge. These waves should be detectable by new instruments coming on line soon (the initial LIGO detectors in Louisiana and Washington have not found anything yet).

The other paper was the one I found most fascinating: "Quantum Mechanics of Black Holes" by the renowned string theorist Edward Witten. Witten notes that the laws of quantum mechanics are reversible (indeed, as all of the fundamental laws of physics). This seems to contradict the possible existence of a black hole. His argument is simple: Take a black hole B and a macroscopic object A, say the spaceship in the awful movie *The Black Hole*, containing Maximilian Schell and Yvette Mimieux. If A and B combine you get a heavier black hole, B*. General relativity says they will inevitably combine if they get close enough, in other words A+B→B*. Quantum mechanics says that B*→A+B should be just as likely. But black holes can never spontaneously regurgitate the spaceship and become lighter. In fact, this is exactly the defining characteristic of a black hole: nothing can escape.

Why isn't the process reversible? The reason has to do with the Second Law of Thermodynamics, which says that in a macroscopic system, any process that reduces the entropy of the universe can't happen. Entropy, which is the measurement of randomness at the atomic level (the number of equivalent states that can describe a system) always increases. Just as a spilled cup of coffee doesn't spontaneously unspill itself, the black hole doesn't emit any macroscopic objects.

When a black hole absorbs any additional mass, it becomes heavier. As a result, the Schwarzschild radius becomes larger. In his greatest contribution to physics, Stephen Hawking showed that the entropy of a black hole is proportional to the surface area at the Schwarzschild radius. In fact, the equation is another one of those ridiculously simple results from complex mathematics:

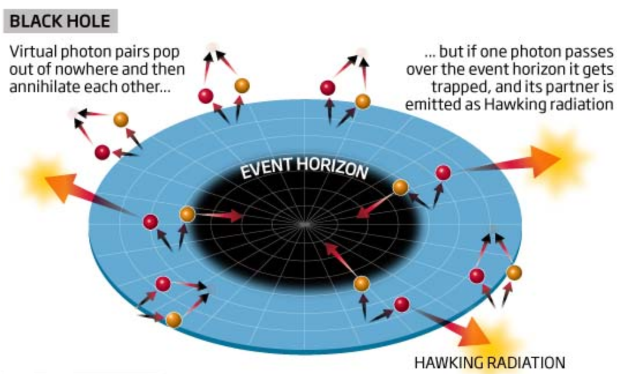
$$S_{BH} = \frac{A}{4\hbar G}$$

where S is the entropy, A the area, ħ the reduced Planck's constant (the actual constant divided by 2π) and G the gravitational constant. When A goes into the black hole, it adds its mass, the radius increases and the entropy increases. It's what the universe wants. It can't be made to decrease. Ergo, Mr. Schell and Ms. Mimieux are lost forever.

Witten also points out that normal objects have an entropy that is proportional to the (3 dimensional) volume of the object, but for black holes it is proportional to the (2 dimensional) surface. This introduces the idea that the surface at the Schwarzschild radius, which I mentioned is not a physical object, behaves like a membrane and can be described mathematically as a membrane. This leads

Witten to the “brane” world of string theory and to the holographic principle, with its idea that the 4-dimensonal spacetime universe we are living in is actually a boundary condition on a 3 dimensional surface.

Another important property of black holes was Hawking’s discovery that black holes actually do radiate because of quantum effects at the event horizon. The Heisenberg uncertainty principle of quantum mechanics holds that pairs of “virtual photons” pop into and out of existence at any time. Normally they merely recombine, maintaining the conservation of energy, but what if they form at the event horizon of a black hole and one falls into the black hole while the other doesn’t? This would add to the mass and entropy of the black hole, but it would also mean that the hole would appear to be emitting a photon, the one that doesn’t fall in.



Formation of Hawking radiation (New Scientist).

Hawking showed that these photons have the spectrum of black body radiation and therefore give the black hole a temperature. The temperature is inversely proportional to the mass. That is, large black holes are very cold, while small black holes are hotter. This also means that eventually black holes will radiate away their mass and energy and disappear. A solar-mass black hole radiates at only 60 nanokelvins, and so it absorbs more photons (from the 2.7º K cosmic microwave background) than it emits. When the universe finally expands sufficiently for the microwave background temperature to drop below 60 nanokelvins, trillions of years from now, stellar-mass black holes will begin to evaporate, and massive black holes even later than that. (In these environments, the entropy of the universe still increases as the holes evaporate). But micro-sized black holes can theoretically form, perhaps during collisions of particles in the Large Hadron Collider or in Brookhaven’s Relativistic Heavy-Ion Collider. These sub-nuclear-sized black holes would almost instantly (10^{-25} seconds or less) radiate away their energy and disappear, which is why concerns expressed by some non-scientists that these instruments might create black holes that will destroy the earth are simply silly.

A fundamental concept of quantum mechanics is that all the information about an object is contained in its wave function. This information persists no matter where in space it is. In the case of objects falling into black holes, Hawking believed that radiation would eventually carry away the information contained in the wave function. His theorem that “black holes have no hair” means that the radiation is independent of the material that fell into the hole in the first place. All black holes are essentially the same in that they can be described by only 3 quantities: mass, charge and angular momentum (remember, the entropy is really a property of the event horizon, not the singularity or the space inside the event horizon). In a sense, the black hole is a fundamental particle! How could it maintain the identity of the material that created it?

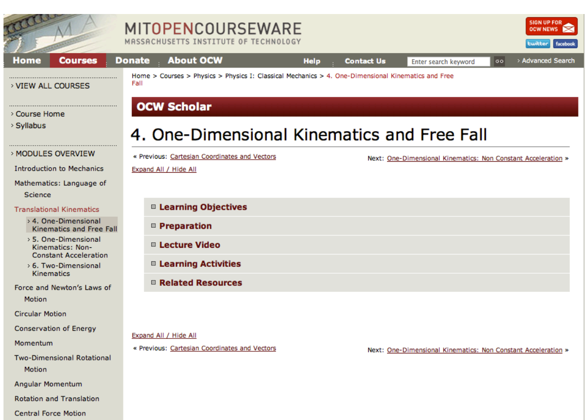
Susskind, one of the world’s leading string theorists, tells a wonderful story in non-mathematical language. He explains the properties of black holes in both relativistic and quantum mechanical terms. The Second Law of Thermodynamics also plays a prominent role and is fairly well explained. Ultimately, Susskind prevails over Hawking: the holographic principle comes to the rescue and preserves the information (in a transformed but nevertheless quantum mechanically valid state). Hawking has acknowledged Susskind’s victory.

If you enjoy challenging yourself with the concepts of relativity and quantum mechanics, you will enjoy Susskind’s book. You will find your understanding of the physics of black holes remarkably enhanced. But many mysteries will remain. Quantum mechanics, relativity and thermodynamics are hard enough by themselves. Mix them together and you’re in for a wild intellectual ride!

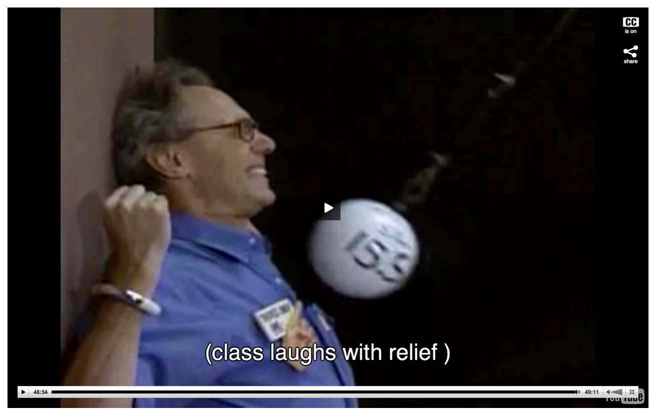
Internet Corner: MIT OpenCourseware
by Tom Boustead

Why do stars shine? Why do planets orbit the Sun? Astronomy turns to physics to answer these questions. But if, like me, your college physics has rusted into brown talcum, some assistance can be required. MIT's OpenCourseware site supplies a remedy.

While the site provides free materials from some 2100 MIT courses, the video/audio lectures offer the richest experience. http://ocw.mit.edu/courses/audio-video-courses/ Click the physics link and navigate to 8.01SC, Classical Physics I, where you can find a syllabus and links to the various lecture topics covering basic Newtonian mechanics--for example, One Dimensional Kinematics and Free Fall. Besides the video lecture, the SC designated courses provide additional resources, such as in-depth lecture notes (Preparation link); slides, solved problems and problem-help videos (Learning Activities) as well as links to other sites (Related Resources).



The highlight of the physics course is the lecturer--Dr. Walter Lewin. His lectures are well organized, easily followed, and laced with entertaining concrete experiments, which prove "that physics works."



The course uses basic calculus. But OpenCourseware offers several SC level courses providing the necessary background.

Editors Note: This is first in a series of reviews of internet sites, blogs and mobile-device apps dealing with amateur astronomy, space science and related fields. WAA members are encouraged to provide a review of their favorite site (Universe Today, Cloudy Nights, etc.) and forward it to the Newsletter.

◀ Curiosity in Action

The light colored peak on the horizon is Mt. Sharp. This is the eventual destination of Curiosity--the roving Mars Science Laboratory. The base of the mountain is about 7 kilometers away.

◀ Savoy Star Party

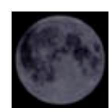
This year's Savoy Star Party at the Shady Pines Campground in Savoy, MA. offered several days of viewing under the dark Berkshires sky. Shown are several scopes setup on the observing field. WAA members Tom Boustead, Kevin and Claudia Parrington were among the attendees.

Almanac

For September 2012 by Bob Kelly


Sep 1


Sep 8


Sep 15

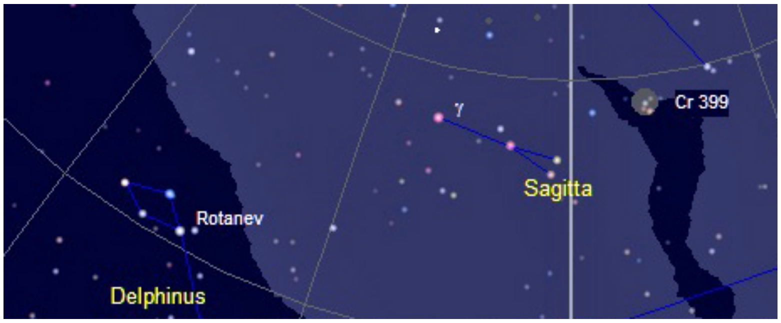

Sep 23

On TV, a young father and mother deliver their kids to various activities, driving at reasonable speeds on residential streets. The disclaimer reads: "Professional driver. Closed course. Do not attempt." Do they really mean, "Don't use our car to drive your kid to ballet?" But in astronomy, everyone can attempt these feats. While some activities need caution – solar observing, moving a 20 ton telescope dome, astronomy is a hands-on, all-ages activity. Let's look at September's skies to see why.

Most of our brightest sky sights are in the morning sky, so let's do some exercises with some fascinating 'lesser lights' of the evening. (No gym needed and these can even be done lying down in a nice lounge chair!) After darkness falls (with no one getting hurt), overhead is Cygnus, the Swan, also known as the Northern Cross. The Cross is visible even in light-polluted skies, and in darker skies, it points toward the Milky Way, which looks like cirrus clouds in a band across the sky. Heading southeast of the Cross, (just below it about 9 or 10pm) is a small set of stars – a four-sided figure and one or two stars separate –

Delphinus, the Dolphin. They fit nicely in a binocular view, as well. One of the Dolphin stars is a colorful double in a telescope. Then scan to the upper right of the Dolphin to find Sagitta, which is the Arrow and really looks like one.

You could, and should, spend lots of time taking in these constellations with the unaided eye and binoculars; you'll see many groupings of stars in this area of the Milky Way (of course, your mileage may vary, depending on your eyesight and binoculars). But go just a bit more to the upper right – with binoculars this time. You should stumble on a star grouping the professionals call Cr 399, but when you attempt it, will look like a coat hanger! Too wide to fit in all but the lowest power telescope views, it's another "just right" view in binoculars or a good finder scope. By the way, the stars in the 'coat hanger' are a random set of stars that just happen to line up to look like something familiar.



Just after sunset, Saturn and Mars linger low in the west-southwest. Saturn is losing its fight to stay out late and will slide behind the Sun, from Earth's point of view, after the end of the month. But this month, that won't stop us from showing off its rings and brightest moons to admirers of the sixth planet. Mars, however, appears to be resisting the call to disappear into the solar glow, running just far enough from the Sun to set two hours after sunset each night into early next year. Mars can do this, in part, because it is gaining speed as it approaches perihelion in January. Mars is really tiny, even in a telescope, but we can wave to the intrepid Mars Rover (Opportunity) and recently arrived Mars Science Laboratory (Curiosity).

Get your finder charts or star program to find Uranus, getting better placed for viewing with optical aid this month. It has an equally bright companion – a star called 44 Piscium – making them look like a double star, closest together on the 22nd and 23rd. See how much magnification you need to tell them apart.

The Moon has its own attractions this month. Look out each evening from the August 31st to September 3rd and from September 29th through October 3rd as Luna rises before the end of twilight each night, giving farmers and romantics more light after sunset. The Moon rides high in the morning sky starting about the 4th. It's a good time to follow the sunset line across the moon with or without optical aid. Think about the 'giant leap' needed for Neil Armstrong to take that small step for us in 1969 (that's a leap we would need a professional driver to take).

The morning sky has two of our brightest lights – Venus almost halfway up in sky, and Jupiter well to its upper right. Venus rises just after 3am, no doubt surprising late-night revelers. If you can drag yourself and your telescope out early before sunrise, Jupiter's belts are more dynamic than usual, changing their widths over the last few months. Jupiter is at quadrature around the 7th, when its moon and their shadows on the planet are farthest apart as seen from Earth.

Venus and Jupiter will make fine viewing as for Subway Astronomers waiting on elevated train lines, subway platforms and at bus stops, as sunrise is delayed to 6:30am in early September to almost 7am by the end of the month. In twilight skies, it's easier to see how Venus is getting more than half-lit and smaller in overall size this month. To the left of blindingly bright Venus is the subtle Beehive cluster, good in binoculars. Later in the month, the bright star near Venus is Leo's brightest, Regulus.

On the morning of the 8th, Jupiter looks like a bright dot just above the Moon. The Moon slides next to Venus on the 12th. Our Moon points out Saturn on the 18th and Mars on the 19th. On the 7th, the Moon passes between the Hyades and Pleiades star clusters, outshining them and hiding them unless you are using binoculars.

Best wishes that the Autumnal Equinox (10:49am on the 22nd) is good to you and I'm hoping that you will try some of these at home.

Bob's blog is at bkellysky.wordpress.com