National Aeronautics and
Space Administration

ASTROLYMPICS

ABOUT ASTROLYMPICS

AstrOlympics is a series of posters, materials and supporting activities that utilize analogies in the teaching of science, engineering, and technology (STEM) to provide multi-generational and family-friendly content in English, Portuguese and Spanish to community centers, libraries, schools small science centers and U.S. Department of State American Spaces/Embassies. The purpose of the program is to connect cross-cutting astrophysics content with everyday as well as Olympic Sport phenomena, helping to demonstrate the universality of physical laws and the connection between our world and the universe as a whole to non-experts.

AstrOlympics is supported by the National Aeronautics and Space Administration under contract NAS8-03060. AstrOlympics was developed by the Chandra X-ray Center (CXC), at the Smithsonian Astrophysical Observatory (SAO), in Cambridge, Massachussetts by:

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DESCRIPTION

Science is everywhere: from here (on Earth, all around you) to everywhere (throughout the Universe). In this exhibit, a series of infographic posters and supporting materials and activities explore various physics concepts such as time, mass, pressure, speed, distance and rotation using themes from the Olympics. The images are aimed at helping to demonstrate the universality of physical laws and the connection between our everyday world and the Universe as a whole to members of the public who may not identify strongly with science.

LEARNING GOALS

By participating in the materials, visitors can:

1. Become intrigued and engaged by the examples of physics
2. Understand basic science principles from familiar examples (analogies)
3. Become observant of physics-based phenomena and begin to question, test, and make their own observations and comparisons
4. Perceive the similarities among phenomena on Earth and throughout the Universe
5. Begin to see the value of scientific inquiry
6. Become comfortable and even excited to think about science in the world around them, and in the greater Universe.

BACKGROUND INFORMATION ON SCIENCE TOPICS:

The athletes that compete in the Olympics can do amazing things. They run faster, jump higher, & spin quicker than most of us ever will.

Many of us are also in awe of what the Universe has to offer. Astronomers have explored the heavens with their telescopes and come up with findings that are so fantastic it can be hard to believe they're real.

What do Olympic athletes and objects in space have in common? The answer is matter in motion, often in extreme examples. Whether it is a human body moving at the fastest speeds possible or the debris from an exploded star blasting through space, the physics of that motion is, in many ways, the same.

The AstrOlympics project explores the spectacular range of science that we can find both in the impressive feats of the Olympic Games as well as cosmic phenomena throughout the Universe. By measuring the range of values for such things as speed, mass, time, pressure, rotation, distance, and more, we can learn not only about the world around us, but also about the Universe we all live in.

The Olympics are an opportunity to behold the limits of human abilities in athletics. After all, the Olympic motto is Latin for "faster, higher, stronger." AstrOlympics enables us to appreciate the feats of the Olympic athletes and then venture far beyond into the outer reaches of space.

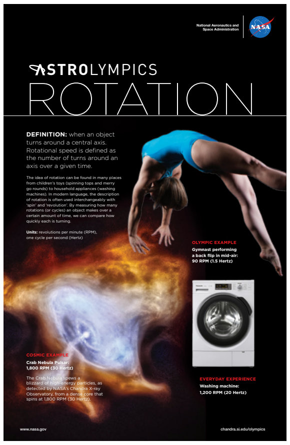
Rotation

When something turns around an axis that doesn't move, we call this rotation. We see rotation all around us – a merry-go-round on a playground, a vinyl record on a turntable, even a washing machine that cleans our clothes. It can often be important – and interesting – to determine just how fast something spins. We call this rotational speed and it is measured as the number of rotations over a certain period of time.
In the Olympic Games, athletes often need to rotate in order to compete in their sports. Gymnasts rotate their bodies during routines, ice skaters rotate during their spins, and aerial skier perform rotations high in the air. How do the spinning accomplishments of these amazing athletes compare to other rotating things that we know about?

Ferris wheels rotate about relatively slowly making one revolution every 600 seconds or so. A ceiling fan, on the other hand, typically rotates twice around every second. This translates into a rotational speed of 0.5 Hertz, the unit we use to talk about rotation.

Hertz=# of rotations per second

That is very quick, but a gymnast doing a back flip rotates with a speed of 1.5 Hertz while an ice skater can spin with a rotational speed of 50 Hertz.



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ASTROLYMPICS

ROTATION

DEFINITION: when an object turns around a central axis. Rotational speed is defined as the number of turns around an axis over a given time.

The idea of rotation can be found in many places from children's toys (spinning tops and merry go rounds) to household appliances (washing machines). In modern language, the description of rotation is often used interchangeably with 'spin' and 'revolution'. By measuring how many rotations (or cycles) an object makes over a certain amount of time, we can compare how quickly each is turning.

Units: revolutions per minute (RPM), one cycle per second (Hertz)

OLYMPIC EXAMPLE

Gymnast performing a back flip in mid-air: 90 RPM (1.5 Hertz)

COSMIC EXAMPLE

Crab Nebula Pulsar: 1,800 RPM (30 Hertz)

The Crab Nebula spews a blizzard of high-energy particles, as detected by NASA's Chandra X-ray Observatory, from a dense core that spins at 1,800 RPM (30 Hertz).

EVERYDAY EXPERIENCE

Washing machine: 1,200 RPM (20 Hertz)

www.nasa.gov

chandra.si.edu/olympics

More information on
http://chandra.si.edu/olympics/#rotation

We also find things in space that rotate. For example, all of the planets, including Earth, rotate around an axis as they make they orbit around the Sun. This rotation, which happens once every 24 hours on Earth, gives us our day and night. The Sun also spins, making one rotation about every 25 days. Elsewhere in space, astronomers have found objects that rotate at a dizzying speed. For example, the dense cores left behind after stars explode – known as neutron stars – can some rotate at remarkable rates. The neutron star at the center of the Crab Nebula is moving at 30 Hertz, in other words making 30 rotations in just one second. That's almost as fast as Olympic ice skaters, which is amazing especially when you consider that the neutron star is over 10 miles or 16 kilometers across!

Perhaps the next time you watch a gymnast tumble or a skiing do a flip, think of the other examples in our lives and across space where rotation is taking place.

Speed

The concept of speed is infused into our lives, whether if it is as we run, drive a car, or travel across the globe. Of course, the athletes in the Olympic Games are often the fastest in the world. This is apparent in many of the Olympic sports from track and field to cycling to downhill skiing and speed skating.

While we are used to asking, 'who is faster,' it's important to understand just what speed represents. Speed is defined as a distance traveled over a certain period of time. In science, we would write this as the equation "speed equals distance divided by time." We've become rather used to this equation – even if we don't realize it. Using this equation, for example, cars provide speed in miles or kilometers per hour. This gives the number of miles or kilometers that would be covered if you moved at that speed for one hour.

The international standard unit for speed is different. The distance is measured in meters, while the amount of time considered is one second. By converting speeds from common experiences into meters per second, we can use this as a reference point for exploring the enormous range of speeds around the world and across the Universe.

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SPEED

DEFINITION: distance traveled over a certain period of time

We often note when something is moving faster or slower than something else. Speed is often used interchangeably with velocity, but they are in fact not the same. Speed measures distance over time, and velocity does this and adds direction. Therefore, two objects may have the same speeds but different velocities if they are moving in different directions.

Units: miles per hour (mph), kilometers per hour (kph), meters per second (mps)

COSMIC EXAMPLE

Cassiopeia A shockwave moving into interstellar medium: 10 million mph (16 million kph)

The supernova remnant Cassiopeia A has a shockwave from the explosion that destroyed the star moving into space at 10 million mph (16 million kph).

SPEED LIMIT 60

EVERYDAY EXPERIENCE

Typical US speed limit on highways: 60 mph (96 kph)

OLYMPIC EXAMPLE

Fastest sprint: 27.8 mph (44.6 kph)

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More information on
http://chandra.si.edu/olympics/#speed

For example, a car moving at 20 miles per hour (or 32 kilometer per hour) is going the equivalent speed of about 9 meters per second. An Olympic athlete, however, can move even faster. Usain Bolt has been clocked running at
12.4 meters per second in the 100-meter sprint. And over a dozen cyclists at the velodrome at the 2012 London Games reached top speeds over 20 meters per second.

These are incredibly impressive feats of speed in the arena of athletic competitions. They also make the speeds found elsewhere even more amazing. For example, the speed of sound in the Earth's atmosphere is about 340 meters per second. Meanwhile, the International Space Station orbits the Earth at about 7,600 meters per second, and the Earth travels around the Sun at some 30,000 meters per second.

Those blistering paces pale in comparison, however, to the Universe's real speedsters. Take, for example, the pulsar known as IGR J11014-6103. This dense core was created when a star collapsed, hurtling this object into space. Astronomers have calculated that this stellar nub is blazing away from its birthplace at a whopping one to two million meters per second. Now that's a speed that anyone -- Olympic athlete or otherwise -- might have to marvel at.

Time

The concept of time permeates our lives. We keep track of time throughout our day on our clocks, phones, or other devices. In the Olympic Games, we use time to dictate how long events are held and to measure how fast athletes perform. Time plays such a crucial role that we have developed many sayings involving time, like “time is running out” or it’s “crunch time.”

But how do you actually define time? Time can be defined as the measurement of repeating patterns. For millennia, the pattern was the rising and setting of the Sun to define the day, and then motion of the Sun across the sky to track a year. Today, we have many mechanical means to generate a repeating pattern from the swinging of a pendulum to the behavior of electrons in so-called atomic clocks.

We need very accurate measurements for the closely contested events in the Olympics, where the difference between gold and silver can be a fraction of a second. However, everyday technologies like GPS require even more precision.

Time and our ability to measure it accurately is also key for many frontiers of science, including astrophysics. The Chandra X-ray Observatory has instruments on board that measure the arrival time of every photon of X-ray light from the objects in space it observes. This timing information can be crucial in learning about cosmic phenomena like how quickly a neutron star spins or how material swirls around a black hole.

Let’s look at some examples. Missy Franklin can cross 100 meters of a swimming pool doing the backstroke in less than 60 seconds. Gamma ray bursts that signal the birth of a black hole last about that long. In the race-walk event at the Olympics, the top athletes finish the 50-kilometer course in just over three and a half hours, or nearly 13,000 seconds. This is a little less time than it takes light from the Sun to reach Neptune. Of course, in the Universe, things can last much longer than that. Our Earth was formed about 4.5 billion years ago, while the Universe itself is thought to be about 13.8 billion years old. That’s a lot of swings of a pendulum to be sure.

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ASTROLYMPICS TIME

DEFINITION: the accurate measurement of repeating patterns

We experience time every day, but it’s not always easy to pin down a precise way to describe it. In science, we define time by our ability to measure it according to some regularly repeating event: the spinning of the Earth on its axis, a pendulum swinging back and forth, or the vibration of atoms under certain conditions. Time and our ability to measure it accurately is key for many frontiers of science.

Units: seconds, years

COSMIC EXAMPLE

Age of the globular cluster 47 Tucanae: about 13 billion years or 4 x 10^{17} sec

Globular clusters like 47 Tucanae are the oldest star systems in our Milky Way galaxy. Astronomers think they formed about 13 billion years ago (4x10^{17} sec).

OLYMPIC EXAMPLE

Time for 50 km (31 mi) race walk: 12,939 sec

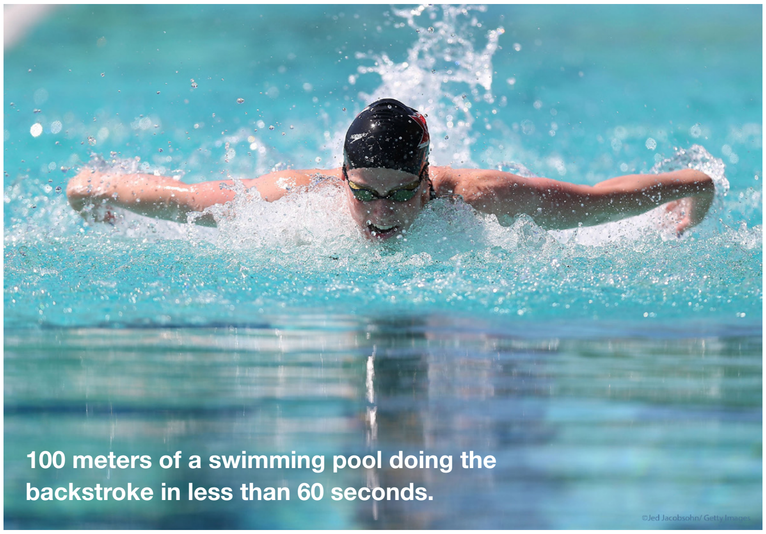
EVERYDAY EXAMPLE

One minute: 60 seconds
One hour: 3,600 seconds
One year: 31,536,000 seconds

www.nasa.gov

chandra.si.edu/olympics

More information on
http://chandra.si.edu/olympics/#time



100 meters of a swimming pool doing the backstroke in less than 60 seconds.

©Jed Jacobsohn/ Getty Images

Mass

How much does something weigh? This is an important question in everyday life, whether it is deciding to try to pick up a piece of furniture or add more resistance during our workout at the gym. However, the better question to ask may be, how much mass does that object contain?

The reason this change in vocabulary can be important is that mass refers to the amount of stuff in an object. Weight, on the other hand, is an object's mass multiplied by the acceleration caused by gravity. On the Earth's surface, there's a consistent tug from gravity. However, if you venture to other planets where gravitational forces are different or into space itself where gravity is virtually non-existent, then that object's weight will change.

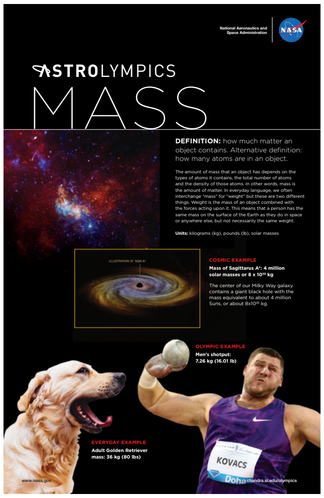
Mass, however, does not change no matter what the environment. For example, the mass of 263 kg, which stands as the current Olympic record for the clean-and-jerk, is the same in Rio as it would be on the Moon. It might be harder to lift it here on Earth with the stronger gravity, but the mass of those plates and bar remain constant because it is an independent value.

On Earth, there are some pretty massive things. The mass of an automobile is about 1,000 to 2,000 kg, while the blue whale is estimated to have a mass of nearly 200,000 kilograms. Humans have gone even further, constructing structures of enormous mass. The Golden Gate Bridge in San Francisco has the mass of about 380 million kg. That pretty big to be sure, but things can get much, much bigger.

But how do we get the mass of objects that we can't physically move or even touch? One way is to observe how much gravitational pull it exerts on other objects or vice versa. Astronomers use this technique to measure the mass of some really enormous things.

Our planet Earth is 6 trillion trillion kilograms, which is a six followed by 24 zeroes. Our Sun is about a million times more massive than that, and the numbers keep going up. For example, the most massive cluster of galaxies in the early Universe that we know about is called El Gordo. Astronomers estimate that it contains the mass of some 3 million billion times the mass of our Sun.

The range of mass in our everyday lives and what we can appreciate in sporting events like the Olympics is just the tip of the proverbial iceberg – especially once we allowed our minds to consider the wonders of space.



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MASS

DEFINITION: how much matter an object contains. Alternative definition: how many atoms are in an object.

The amount of mass that an object has depends on the types of atoms it contains, the total number of atoms and the density of those atoms. In other words, mass is the amount of matter. In everyday language, we often interchange "mass" for "weight" but these are two different things. Weight is the mass of an object combined with the forces acting upon it. This means that a person has the same mass on the surface of the Earth as they do in space or anywhere else, but not necessarily the same weight.

Units: kilograms (kg), pounds (lb), solar masses

COSMIC EXAMPLE

Mass of Sagittarus A*: 4 million solar masses or 8 x 10^{36} kg

The center of our Milky Way galaxy contains a giant black hole with the mass equivalent to about 4 million Suns, or about 8x10^{36} kg.

OLYMPIC EXAMPLE

Men's shotput: 7.26 kg (16.01 lb)

EVERYDAY EXAMPLE

Adult Golden Retriever mass: 36 kg (80 lbs)

www.nasa.gov

chandra.si.edu/olympics

More information on
http://chandra.si.edu/olympics/#mass

Distance

We frequently ask: how far away is that? The concept of distance is very familiar to us. After all, we need to factor in distance whether it's for a trip around the corner or across the country. One way to define distance is the ground covered between two points.

Distance plays an important role in many Olympic sports. The ability to travel the distance around a track, across a swimming pool, or down the road faster than anyone else may lead to a gold medal. Olympic events like the marathon show how some athletes can excel over what most of us consider to be a very long distance.

Despite how large some Olympic distances may seem, they are just a tiny fraction of the lengths we see across space. For comparison purposes, let's look at everything in the widely accepted unit of meters. In the metric system, a kilometer simply means a thousand meters (which is equivalent to about 0.62 miles). The longest Olympic track and field event in terms of distance is the 50-kilometer, or 50,000-meter, race walk.

By comparison, it is about 7700 kilometers, or 7.7 million meters, from New York to Rio de Janeiro for those athletes and spectators making that trip. The distance around the equator of Earth is about 40 million meters. In space, however, distances get much, much bigger. It's about 150 billion meters to the Sun, and 40 quadrillion meters to Proxima Centauri, the next nearest star to us. That's a 40 followed by another 15 zeroes.

Because numbers get so large so quickly when talking about objects in space, astronomers most often use the unit of light years to describe distance. While it sounds like an amount of time, a light year is, in fact, a distance. It is equivalent to how far light travels over the course of one year, roughly 9,000 trillion meters. Rather than keeping track of all of those zeroes, we can that same distance to Proxima Centauri as being about 4.2 light years away. That's helpful because Proxima Centauri is actually very close to us, compared to many other things in space. Take the center of Milky Way galaxy, which is about 26,000 light years away. And astronomers have observed light left over from the Big Bang at some 13.7 billion light years away.

So whether it is around a track or across a galaxy, distance is something worth keeping in perspective.

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DISTANCE

DEFINITION: how far away an object is or the amount of ground an object has covered in its motion

We frequently ask: how far away is that? The concept of distance is very familiar to us for things we encounter on Earth. One way to describe distance is as the ground covered between two points. When we think about things on different scales, we find that distances can stretch (or shrink) almost as far as our imaginations.

Units: meter (m), kilometers (km), feet, miles, light years (A light year is the distance light travels in a year, about 6 trillion miles/9.5 trillion km).

OLYMPIC EXAMPLE

Olympic distance between archer and target: 70 meters (230 feet)

COSMIC EXAMPLE

Distance to the Bullet Cluster: about 3.4 billion light years ($3.2x10^{22}$ km)

The Bullet Cluster is the site of a spectacular collision between two galaxy clusters located at a distance of some 3.4 billion light years or $3.2x10^{22}$ km.

EVERYDAY EXPERIENCE

Distance from one end of Brooklyn Bridge to the other: 1,797 meters (5989 feet)

www.nasa.gov

chandra.si.edu/olympics

More information on http://chandra.si.edu/olympics/#distance

Olympian Stacie Powell

From the Chalkboard to the Diving Board

Stacie Powell is currently a Ph.D. student in astrophysics at Institute of Astronomy at the University of Cambridge, England. She competed in the 2012 Olympic Games in London in the 10-meter diving platform competition. Stacie took some time from her busy schedule to discuss her academic and career path thus far. For an interview with Stacie, go to **http://chandra.si.edu /blog/node/410**

SUGGESTIONS FOR HANDS-ON ACTIVITIES

Math exercises

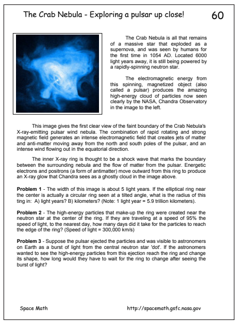
Connect to NASA Space Math problems

ACTIVITY 1

Pulsars: The Crab Nebula (as seen on Rotation)
Exploring a pulsar up close! (problem #398)

Core concept: Students work with a photograph to determine its scale and the time taken by light and matter to reach a specified distance.

Grade: 6-8 | Topics: Scale drawings; unit conversion; distance = speed x time



The Crab Nebula - Exploring a pulsar up close! 60

The Crab Nebula is all that remains of a massive star that exploded as a supernova, and was seen by humans for the first time in 1054 AD. Located 6000 light years away, it is still being powered by a rapidly-spinning neutron star.

The electromagnetic energy from this spinning, magnetized object (also called a pulsar) produces the amazing high-energy cloud of particles now seen clearly by the NASA, Chandra Observatory in the image to the left.

This image gives the first clear view of the faint boundary of the Crab Nebula's X-ray-emitting pulsar wind nebula. The combination of rapid rotating and strong magnetic field generates an intense electromagnetic field that creates jets of matter and anti-matter moving away from the north and south poles of the pulsar, and an intense wind flowing out in the equatorial direction.

The inner X-ray ring is thought to be a shock wave that marks the boundary between the surrounding nebula and the flow of matter from the pulsar. Energetic electrons and positrons (a form of antimatter) move outward from this ring to produce an X-ray glow that Chandra sees as a ghostly cloud in the image above.

Problem 1 - The width of this image is about 5 light years. If the elliptical ring near the center is actually a circular ring seen at a tilted angle, what is the radius of this ting in: A) light years? B) kilometers? (Note: 1 light year = 5.9 trillion kilometers).

Problem 2 - The high-energy particles that make-up the ring were created near the neutron star at the center of the ring. If they are traveling at a speed of 95% the speed of light, to the nearest day, how many days did it take for the particles to reach the edge of the ring? (Speed of light = 300,000 km/s)

Problem 3 - Suppose the pulsar ejected the particles and was visible to astronomers on Earth as a burst of light from the central neutron star 'dot'. If the astronomers wanted to see the high-energy particles from this ejection reach the ring and change its shape, how long would they have to wait for the ring to change after seeing the burst of light?

Space Math http://spacemath.gsfc.nasa.gov

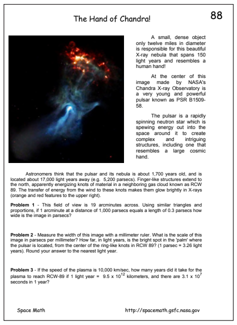
http://spacemath.gsfc.nasa.gov/weekly/7Page60.pdf

ACTIVITY 2

Neutron Stars: The Hand of Chandra (problem #234), a neutron star like shown on Pressure

Core concept: Students use an image from the Chandra Observatory to measure a pulsar ejecting a cloud of gas.

Grade: 6-8 | Topics: Scientific Notation; proportions; angle measure



The Hand of Chandra! 88

A small, dense object only twelve miles in diameter is responsible for this beautiful X-ray nebula that spans 150 light years and resembles a human hand!

At the center of this image made by NASA's Chandra X-ray Observatory is a very young and powerful pulsar known as PSR B1509-58.

The pulsar is a rapidly spinning neutron star which is spewing energy out into the space around it to create complex and intriguing structures, including one that resembles a large cosmic hand.

Astronomers think that the pulsar and its nebula is about 1,700 years old, and is located about 17,000 light years away (e.g. 5,200 parsecs). Finger-like structures extend to the north, apparently energizing knots of material in a neighboring gas cloud known as RCW 89. The transfer of energy from the wind to these knots makes them glow brightly in X-rays (orange and red features to the upper right).

Problem 1 - This field of view is 19 arcminutes across. Using similar triangles and proportions, if 1 arcminute at a distance of 1,000 parsecs equals a length of 0.3 parsecs how wide is the image in parsecs?

Problem 2 - Measure the width of this image with a millimeter ruler. What is the scale of this image in parsecs per millimeter? How far, in light years, is the bright spot in the 'palm' where the pulsar is located, from the center of the ring-like knots in RCW 89? (1 parsec = 3.26 light years). Round your answer to the nearest light year.

Problem 3 - If the speed of the plasma is 10,000 km/sec, how many years did it take for the plasma to reach RCW-89 if 1 light year = 9.5 x 10^{12} kilometers, and there are 3.1 x 10^{7} seconds in 1 year?

Space Math http://spacemath.gsfc.nasa.gov

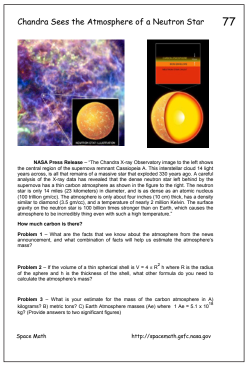
http://spacemath.gsfc.nasa.gov/weekly/5Page88.pdf

ACTIVITY 3

Exploded Stars: Cas A, exploded star as seen on Speed.
Chandra Observatory Sees the Atmosphere of a Neutron Star (problem #283)

Core concept: Students determine the mass of the carbon atmosphere of the neutron star Cas-A.

Grade: 8-10 | Topics: Volume of spherical shell; mass = density x volume



Chandra Sees the Atmosphere of a Neutron Star 77

NASA Press Release – "The Chandra X-ray Observatory image to the left shows the central region of the supernova remnant Cassiopeia A. This interstellar cloud 14 light years across, is all that remains of a massive star that exploded 330 years ago. A careful analysis of the X-ray data has revealed that the dense neutron star left behind by the supernova has a thin carbon atmosphere as shown in the figure to the right. The neutron star is only 14 miles (23 kilometers) in diameter, and is as dense as an atomic nucleus (100 trillion gm/cc). The atmosphere is only about four inches (10 cm) thick, has a density similar to diamond (3.5 gm/cc), and a temperature of nearly 2 million Kelvin. The surface gravity on the neutron star is 100 billion times stronger than on Earth, which causes the atmosphere to be incrredibly thing even with such a high temperature."

How much carbon is there?

Problem 1 – What are the facts that we know about the atmosphere from the news announcement, and what combination of facts will help us estimate the atmosphere's mass?

Problem 2 – If the volume of a thin spherical shell is $V = 4 \pi R^2 h$ where R is the radius of the sphere and h is the thickness of the shell, what other formula do you need to calculate the atmosphere's mass?

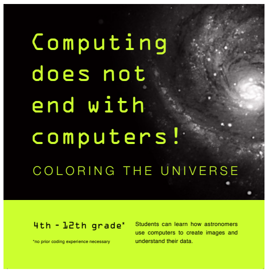
Problem 3 – What is your estimate for the mass of the carbon atmosphere in A) kilograms? B) metric tons? C) Earth Atmosphere masses (Ae) where 1 Ae = 5.1 x 10^{18} kg? (Provide answers to two significant figures)

Space Math http://spacemath.gsfc.nasa.gov

http://spacemath.gsfc.nasa.gov/weekly/5Page88.pdf

Coding workshop:

Connect to a simple coding activity (no previous coding skill required) for grades 4-12. This image processing exercise shows participants how basic coding is used to add color, filters and layers to science images. The video tutorial takes you step-by-step. Requires laptops for the students and internet connection to run the coding and video tutorial in a browser.



Computing does not end with computers!

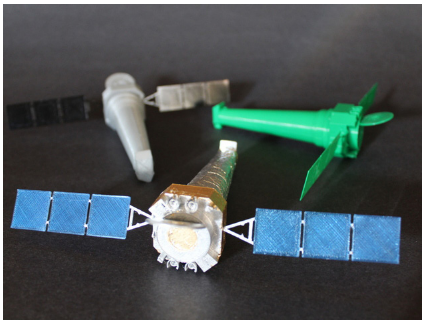
COLORING THE UNIVERSE

4th - 12th grade*

*no prior coding experience necessary

Students can learn how astronomers use computers to create images and understand their data.

http://event.pencilcode.net/



3D Printing an exploded star

If you have a 3D printer, you can print out Cassiopeia A, which is shown on the Speed poster. Data of Cassiopeia A was captured by NASA's Chandra X-ray Observatory and combined with infrared and visible light to make the first ever free 3D model of an exploded star. Small prints around 3 in/7.62cm in size take about 2 hours to print, depending on the printer type.

http://chandra.si.edu/3dprint

Science demonstrations

1. Distance to the Moon

To calculate the distance between scale models of Earth and the Moon. In this activity students will use simple sports balls as scale models of Earth and the Moon. Given the astronomical distance between Earth and the Moon, students will determine the scale of the model system and the distance that must separate the two models.

2. Length of day

The length of the day is something we take for granted. Yet, much can be learned about the day – and the way the Earth moves -- from careful observations of the Sun and a more distant star, over as little as 24 hours, with a home-made viewer and a good clock.

National Aeronautics and Space Administration

OUR EYE ON THE SUN

THE SCIENCE OF THE SUN

Secondary Learning Unit

Educational Product

Educators | Grades 7-12

EG-2010-01-032-GSFC

SDO | solar dynamics observatory

www.nasa.gov

Participants will use the clock to check the clock time of the Sun's passage by the ground mark for several days in a row. At home during the evening hours, students can also measure the clock time when a star of their choice falls into alignment.

3. Measuring Time

Understanding the relationship between Earth and the Sun is a fundamental concept in science. In this unit students focus on the Sun as the cause of seasons on earth, and the study of the Sun its self. Beginning with the seasons, students explore the relationship between the Sun and Earth in space. With that foundation in place,

1 http://ares.jsc.nasa.gov/education/program/ExpMoon/DistanceMoon.pdf

2 http://pumas.nasa.gov/examples/index.php?id=57

3 http://sdo.gsfc.nasa.gov/assets/docs/UnitPlanSecondary.pdf