



# 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.

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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.

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



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

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 skier 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.

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.



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

## 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.



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

## 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.

**ASTROLYMPICS**  
**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 kind of stuff it contains. The total number of atoms, the size of each atom, and the number of molecules are all important. Mass is not the same as weight. Mass is a measure of an object's resistance to acceleration. Mass is a scalar quantity and is measured in kilograms (kg).

**OLYMPIC EXAMPLE:** Mass of Neptune is 4.6 billion solar masses or  $4.6 \times 10^6 M_{\odot}$

The center of our galaxy, the galaxy contains a giant black hole with the mass equivalent to about 4 million suns, or about  $4 \times 10^6 M_{\odot}$ .

**ASTROLYMPIC EXAMPLE:** A gold medal weighs about 350 grams (0.35 kg).

**OLYMPIC EXAMPLE:** Mass of a shot put is 7.26 kg (16.1 lb).

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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.

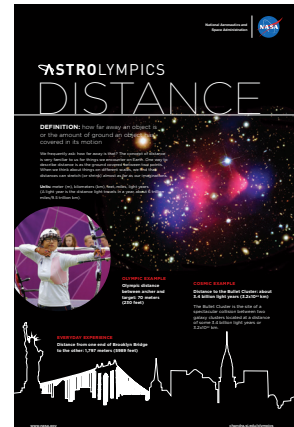
Because numbers get so large so quickly when talking about objects in space, astronomers most often use the unit of light years to describe distance. While it sounds like an amount of time, a light year is, in fact, a distance. It is equivalent to how far light travels over the course of one year, roughly 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.

## 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>



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



# 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 star that exploded in A.D. 1054. The star was so bright that the Chinese recorded its appearance in the sky. The star was so bright that it was visible in the daytime for about 23 days. The star was so bright that it was visible in the daytime for about 23 days. The star was so bright that it was visible in the daytime for about 23 days.

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Problem 1 - The width of this image is about 5 light years. If the distance to the Crab Nebula is 6,500 light years, how long would it take for light from the star to reach Earth? (Distance = Speed x Time)

Problem 2 - The Crab Nebula is about 5 light years wide. If the distance to the Crab Nebula is 6,500 light years, how long would it take for light from the star to reach Earth? (Distance = Speed x Time)

Problem 3 - The Crab Nebula is about 5 light years wide. If the distance to the Crab Nebula is 6,500 light years, how long would it take for light from the star to reach Earth? (Distance = Speed x Time)

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



The Hand of Chandra is a neutron star pulsar with a long tail of gas and dust trailing behind it. The pulsar is a rapidly rotating neutron star that emits a beam of electromagnetic radiation. The tail is a long stream of gas and dust that is ejected from the pulsar. The tail is a long stream of gas and dust that is ejected from the pulsar.

Problem 1 - The width of this image is about 10 light years. If the distance to the Hand of Chandra is 10,000 light years, how long would it take for light from the star to reach Earth? (Distance = Speed x Time)

Problem 2 - The Hand of Chandra is about 10 light years wide. If the distance to the Hand of Chandra is 10,000 light years, how long would it take for light from the star to reach Earth? (Distance = Speed x Time)

Problem 3 - The Hand of Chandra is about 10 light years wide. If the distance to the Hand of Chandra is 10,000 light years, how long would it take for light from the star to reach Earth? (Distance = Speed x Time)

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



Chandra Sees the Atmosphere of a Neutron Star. The Chandra X-ray Observatory has seen the atmosphere of the neutron star Cas A. The atmosphere is a thin layer of gas and dust that surrounds the star. The atmosphere is a thin layer of gas and dust that surrounds the star.

Problem 1 - What are the facts that we know about the atmosphere from the image? (Distance = Speed x Time)

Problem 2 - If the volume of a thin spherical shell is  $V = 4\pi r^2 \Delta r$ , where  $r$  is the radius of the sphere and  $\Delta r$  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 Cas A? (Distance = Speed x Time)

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

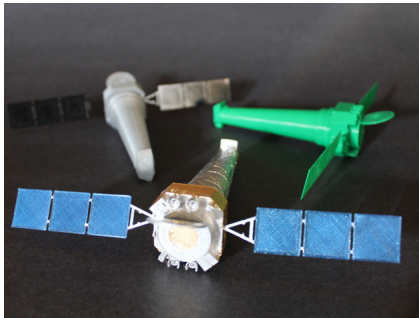
<http://spacemath.gsfc.nasa.gov/weekly/5Page88.pdf>

## 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.



<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

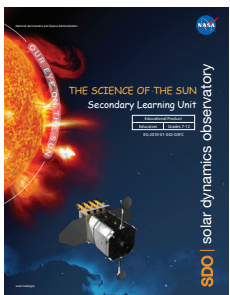


### 1. Distance to the Moon

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.



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>