National Aeronautics and
Space Administration

Educational Product	
Educators & Students	Grades 9 - College

Educational Brief

CHIPS SCIENCE INVESTIGATION

Exploring the Interstellar Medium

Objectives
Students will learn about the Interstellar Medium and the Local Bubble that the Sun is inside.
Students will learn about the densities in the Interstellar Medium and the interactions between light and matter within it.
Students will learn how matter and energy are conserved between Stars and the Interstellar Medium.
Students will explore the concepts of heat and temperature and learn of the distinction between the two.

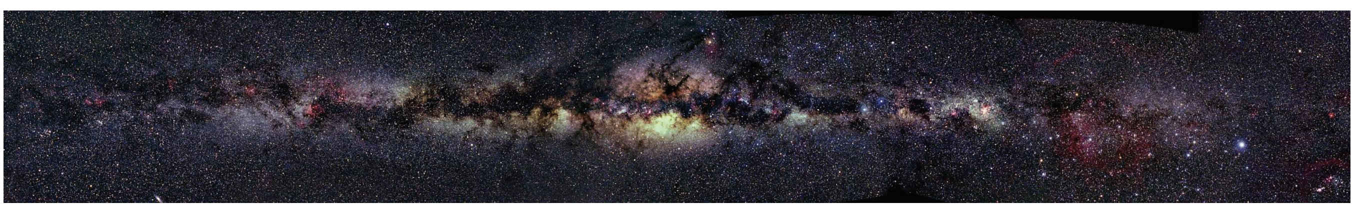
Note to teachers: This brief is intended for use in high school and college classrooms. It may be handed out to these students to read on their own or it may serve as a reference for a teacher-led lesson in the classroom. Parts of this brief may be adapted for use in middle school classrooms, especially the activities.

National Science Education Standards
Science as Inquiry
Physical Science
- Structure of atoms
- Structure and properties of matter
- Motions and forces
- Conservation of energy
- Interactions of energy and matter

Earth and Space Science
- Origin and evolution of the Earth system
- Origin and evolution of the Universe

NCTM Math Standards
Number & Operations
Geometry
Measurement
Problem Solving
Communication
Connections

Materials
- Oven with Stovetop
- Cooking Pot
- Drinking Glasses or Beakers
- Water & Ice Cubes
- Thermometers
- Stopwatch
- Fishbowl or Beaker
- Overhead Projector
- Milk



If you go out at night, far away from the city lights, you can see a band of diffuse light stretching across the sky. This is the Milky Way Galaxy, an enormous disk of stars. Our Sun is inside this disk about two-thirds of the way out from the center. All of the thousands of individual stars visible to the naked eye at night are also inside this disk. In the Milky Way Galaxy alone, there are over 100 billion stars. The disk of the Milky Way is about 100,000 light-years in diameter and about 1,000 light-years thick. This means the average distance between stars is over four light-years. A light-year is the distance light travels in one year (9.45 trillion kilometers). The nearest star to the Sun is Proxima Centauri and is 4.2 light-years away. To give you a sense of scale, if the Sun were the size of a grapefruit (10 cm in diameter) then Earth would be the size of a pinhead located 10.7 meters away from it. If this grapefruit-Sun were located in Los Angeles, California then Proxima Centauri would be another grapefruit located in New York City. Space is vast! Many people have the mistaken idea that space is completely empty, a perfect vacuum. In fact, the space between stars in the Milky Way Galaxy is filled with very thin gases that can be either hot or cold, and microscopic grains of dust. This matter is called the *Interstellar Medium* (ISM) and may contain important clues about the formation and evolution of planets, stars, and galaxies. Let us now explore this Interstellar Medium and learn about some of the critical roles it plays in the Universe.

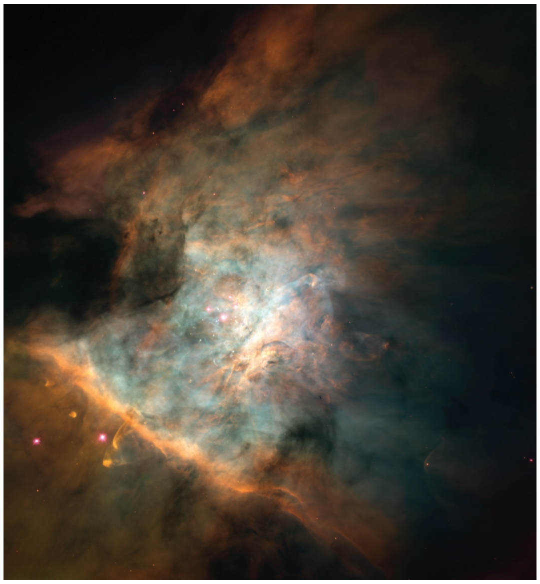


Figure 1: The Orion Nebula. Visible in the winter evening skies as the middle star of Orion's sword, this star-forming region is 1,500 light-years away and 26 light-years across. This image is of the central 2.5 light-year region.

The Interstellar Medium

The vast spaces between stars in a galaxy is not completely empty, it is sparsely sprinkled with gas and dust. This 'stuff' between the stars is known as the Interstellar Medium. About 99% of the ISM is hydrogen and helium gas; the remaining 1% consists of gases and dust of heavier elements. The gas is extremely dilute, with an average density of about 1 atom per cubic centimeter. The air we breathe is approximately 30 quintillion (30,000,000,000,000,000,000) times more dense than the ISM. Picture this: an "empty" coffee mug in the ISM would contain about 500 hydrogen atoms. The same "empty" coffee mug sitting on your desk contains about 1,500 quintillion (1.5×10^{21}) gas molecules - mostly nitrogen, oxygen, and carbon-dioxide. The typical density of the dust in interstellar space is even less than that of the gas. In one cubic *kilometer* of interstellar space you would find, on average, only 1,000 grains of dust. So, while the space between stars is not a *perfect* vacuum, it has a density about one trillion times less than the best "hard vacuums" ever created in laboratories on Earth. At such low densities, it may seem to you that the ISM is barely there at all. But remember, space is huge. All that matter adds up in the vastness between the stars. For example, the inner 16 light-years of the Orion Nebula contains enough mass in gas and dust to make up more than 300 Suns.

The dust in the ISM is made of tiny, irregularly shaped particles of silicates (minerals with silicon and oxygen as the fundamental ingredients), carbon, ice, and iron. The typical size of a dust grain is 0.1 microns (1 micron is 1 millionth of a meter). The wavelengths of visible light are of similar size (0.4 – 0.7 microns), which means visible light can be absorbed and scattered by the dust grains. In areas where the dust is thicker than average, the light from nearby stars can be completely blocked - similar to the way dark clouds block light from the Sun. Figure 2 shows the Horsehead Nebula (*nebula* is a Latin word meaning *cloud*) - the dark area in the center of the photograph (shaped like a horse's head) is a thick cloud of interstellar dust blocking the light. Thinner clouds of interstellar dust may dim the light passing through, without completely blocking it. This is known as *extinction*. Because the typical sizes of interstellar dust grains are similar in size to shorter (blue) wavelengths of visible light, blue light is scattered and absorbed more effectively than red light. This means that most of the light that reaches us through the interstellar dust is reddish. This is known as *interstellar reddening*. A similar process happens here on Earth at sunset. Molecules of air on Earth scatter blue light more than red light, and when the Sun is low on the horizon its light passes through so much air that there is almost no blue light left in it, and the Sun appears a reddish-orange color.

Figure 2: The Horsehead Nebula

In nebulae, light from nearby stars can also be reflected off of the interstellar dust and gas, similar to the way light from a car's headlights can reflect off fog. Because blue light is more easily scattered (and reflected) by clouds of dust and gas, some nebulae appear to have a bluish color and are called *reflection nebulae*. The sky of Earth is blue for the same basic reason. As sunlight passes through the atmosphere blue light is scattered into random directions by nitrogen molecules in the air.

In addition to absorbing and scattering light, the gas in the ISM can emit its own light. In regions containing very hot, newly-formed stars, *ultraviolet radiation* emitted from the stars strips electrons from the atoms of the hydrogen gas, a process called *ionization*. When these electrons recombine with the *ionized* hydrogen, red light is emitted from the hydrogen gas. This accounts for the red colors in photographs of nebulae, such as the Orion and Trifid Nebulae (Figures 1 and 3). In the image of the Trifid Nebula in Figure 3 we see part of the cloud glowing red because young, hot stars within are ionizing it. The outer parts of the nebula are reflecting blue light from those same hot stars. There are also dark lanes of concentrated dust, which are blocking the light of stars and gas behind them.

Figure 3: The Trifid Nebula

The hydrogen gas in the ISM can also form relatively cool clouds that emit light in the radio band of the electromagnetic spectrum. These cool clouds of hydrogen can collapse under their own weight. It is here, in these dense, collapsed clouds known as *stellar nurseries*, that new stars and planetary systems can form out of the ISM matter.

Understanding the Life Cycle of Stars and the ISM

The ISM literally contains the seeds of future stars, and all the stars we see were once formed out of the same kind of diffuse gas and dust. When the gas in the ISM cools, gravity takes hold and clouds begin to collapse. The gas forms clumps that can develop into stars and planets. In fact, this is probably how our solar system was formed. One of the biggest puzzles in astrophysics is the process that turns these very diffuse, hot and cold gases and dust in the ISM into stars. The enhanced-color photograph from the Hubble Space Telescope in Figure 4, captures various stages of the star life cycle. To the upper left of center is the blue supergiant star named Sher 25, which is near the end of its life. Near the center is a cluster dominated by young, hot stars. The three small dark clouds in the upper right corner are so-called *Bok globules*, which are in an early stage of star formation. The gold-colored clouds are *ionized hydrogen gas* in the ISM. [NOTE: this ionized hydrogen appears gold rather than red because of the color enhancement done during the processing of the image]

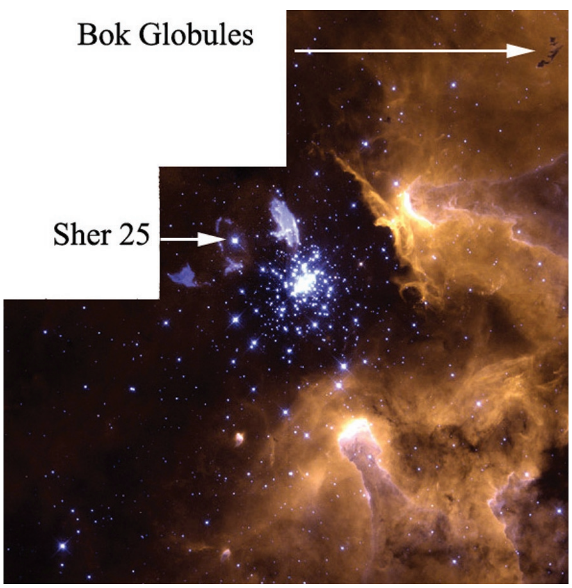


Figure 4: NGC 3603

Figure 5: The Crab Nebula

Processes that heat the ISM are fairly well understood. Stars blow winds of gas and dust particles off their surfaces throughout their lives. The most massive stars blow the strongest winds transferring huge amounts of energy into the ISM. Very massive stars also violently explode only a few million years after their formation, stirring and heating the gas out of which they formed. Such an exploding star is called a *supernova*. These injections of energy from supernovae and stellar winds profoundly affect the ISM and determine the rate at which new stars form. However, even after decades of study, the process by which this diffuse gas in the ISM cools and influences the star formation remains one of the enduring puzzles of astrophysics. In order to understand how stars form, it is necessary to understand how this extremely hot gas cools. NASA's new mission, the Cosmic Hot Interstellar Plasma Spectrometer (CHIPS), is studying the cooling of gas in the Sun's galactic neighborhood.

The Local Bubble: Our Astronomical Neighborhood

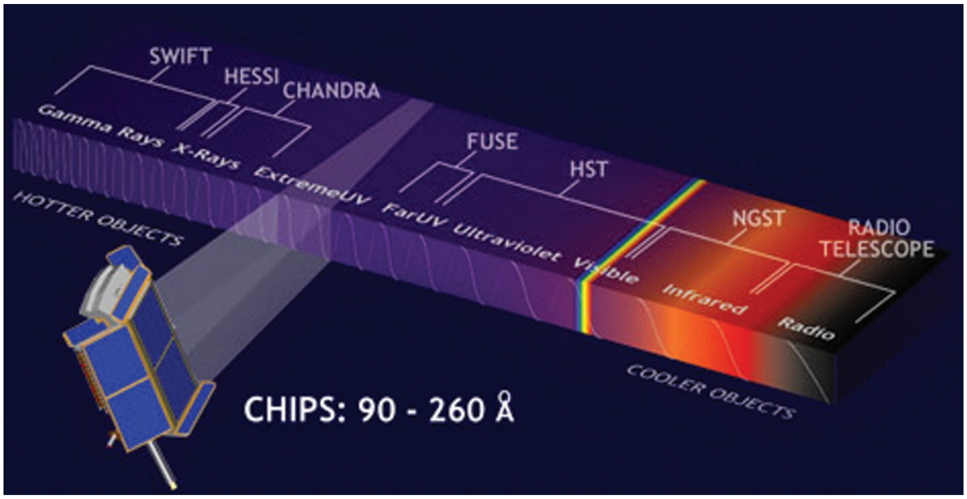
Our solar system is located in an unusual region of space called the Local Bubble. The Local Bubble is about 300 light years in radius and is filled with extremely low density gas (about 0.001 gas atoms per cubic centimeter) - this is much less dense than the ISM surrounding it. The coffee mug that would contain about 500 hydrogen atoms in the average ISM would only contain 1 hydrogen atom (or maybe none at all!) if it were in the Local Bubble. This gas is also extremely hot—about 1 million degrees Kelvin (1.8 million degrees Fahrenheit), or almost 200 times as hot as the surface of the Sun! Despite such high temperatures, if you were to stick your unprotected hand into the Local Bubble environment it would freeze. This is due to the difference between temperature and heat. Temperature is a measure of the average energy of motion per gas particle. Heat is a measure of the sum of energy from the motion of all the gas particles. The gas particles in the Local Bubble may have very high energies on average (temperature), but because the density is so low there would be few of them interacting with your hand. So, very little heat would be felt. It is the extremely diffuse gas, inside the Local Bubble, that the CHIPS mission is studying.

Figure 6: N70 in the LMC

Astronomers hypothesize that the Local Bubble may have been created by a supernova explosion several million years ago - that is, the explosion "blew" most of the gas and dust from the interstellar medium outward. Supernovas are one of the most violent and energetic events in the Universe. They can result from either the death of a star many times more massive than the Sun or from a strange kind of star, called a *white dwarf*, that accumulates matter from a companion until it explodes. In 1054 A.D., Chinese astronomers recorded a 'guest star' that appeared in the constellation of Taurus for several days. For a short while this star shined as brightly as the Moon. When modern telescopes peered at the location recorded by the Chinese astronomers, they found the remains of a star that had blown itself up—the Crab Nebula (Figure 5). The Crab Nebula is an example of a young *supernova remnant*. It is still relatively compact (only 10 light-years in diameter) and expanding rapidly with filamentary structures inside. The bubble, named N70, in Figure 6 is located in the Large Magellanic Cloud (LMC), a small galaxy orbiting the Milky Way. It is about 150 light-years in radius and is filled with hot tenuous gas. It is likely the result of not just supernova explosions but also strong stellar winds from hot massive stars inside the bubble. Because the Local Bubble is much larger, it is probably the remnant of a much more ancient supernova than either the Crab or the supernovas that created N70.

CHIPS: A Mission to Study the Local Bubble

CHIPS (Cosmic Hot Interstellar Plasma Spectrometer) is a NASA satellite-based observatory, launched in January 2003 to study the million degree gas in the Local Bubble. Some hypotheses predict that the majority of energy radiated by this hot gas occurs in the short-wavelength, extreme ultraviolet region of the *electromagnetic spectrum*. This is a relatively unsurveyed band, centered around 170 Å that CHIPS is studying. One Å (Angstrom) is 10 billion times smaller than a meter. CHIPS will observe extreme ultraviolet light emitted by the gas in the *Local Bubble* and spread it into a spectrum. The nature of the emissions at this wavelength may contain important clues about the process of cooling that takes place in the *Local Bubble* ISM.



The key questions about the ISM that the CHIPS mission will seek to answer are:

- What type of electromagnetic radiation is emitted most by local hot gas?
- By which physical processes does the hot interstellar gas of the Local Bubble cool?
- What is the shape of the Local Bubble?
- What is the physical history of the Local Bubble?
- How can this knowledge be applied to other hot and diffuse regions in the Universe?

Review Questions and Problems

1) The nearest large spiral galaxy to us is the Andromeda Galaxy, which is visible to the naked eye in the constellation of Andromeda. Andromeda is slightly larger than the Milky Way; it is 135,000 light-years in diameter. It has roughly twice the number of stars as the Milky Way, which has around 100 billion stars. Assume that the shape of the galaxy is a simple disk with a thickness of 1,000 light years and that stars are evenly distributed throughout it.

   Show all work and for your unit of distance use light-years.

   a) Calculate the number of stars per unit volume (called *number density*) in Andromeda. (HINT: The units of length given are light-years, thus your units of volume should come out to be ***light-years^3*** and the units of number density would be ***# of stars/light-year^3***)
   b) Next, calculate the volume of empty space surrounding every star. (HINT: what would the units of this quantity be and what mathematical operation will give those units given the calculation in part a.?)
   c) Finally, calculate the average separation between stars in Andromeda. (HINT: the separation between stars is a linear measurement, not a cubic one).
2) Calculate the volume of interstellar space in an average part of the Galaxy that would hold the same number of gas particles as a coffee mug sitting on your desk on Earth. (HINT: Set up a ratio and let units be your guide)
3) The law of conservation of matter states that matter cannot be created nor destroyed; it can only change form. Explain how the matter in the ISM demonstrates this concept.
4) Name at least two ways the ISM can be heated.
5) What is the Local Bubble, and what are some possibilities for how it formed?

Classroom Activities:

Why is the sky blue and sunsets red?

In this activity students will experience a demonstration of light scattering that explains the blue colors in the ISM nebulae, and the reddening of stars viewed through the ISM. It also explains the blue appearance of the sky on Earth and the reddish appearance of the Sun during sunsets. This demonstration is best done before or during the lesson on the ISM when light scattering is discussed.

1) Obtain a fishbowl, pitcher, or beaker made of transparent glass or plastic. Fill it with water and place it on an overhead projector.
2) Darken the room as much as possible and turn on the overhead projector lamp. Light should now be passing through the container of water and the silhouetted outlines of it should be visible on the projector screen. Ask students to comment on the appearance of the container itself and on its image on the screen. The water in the container should be clear and the image of it on the projector should be white.
3) Next you will add some drops of whole milk into the water. Before you do, have students predict what will happen to the appearance of the water in the container and the image on the screen. Make sure they write down their predictions and give their reasoning. Then add the drops into the water and stir. Add enough to make the water cloudy but not opaque (3-4 drops). Now ask students to observe the appearance of the water. They should see that the water has taken on a pale blue color. Have them attempt to explain this color. The blue color is a result of the light scattering off fat and protein molecules from the dissolved milk. Students may have a hard time telling that the milky-water is glowing bluish. Place a piece of white poster board behind the fishbowl. The water is more obviously bluish when contrasted with the pure white board.
4) Next draw the students' attention to the image on the screen. They should now see the water in the container appearing red. Again ask students to explain this. Because much of the bluer wavelengths have been scattered out of the white light passing through the milky water, mostly redder colors have made it through. The color may initially appear more yellowish, but if you slowly add more milk the color will grow more red and dim. This is what happens to light of stars passing through the ISM. Starlight experiences *reddening* and *extinction*.
5) Lastly ask students to draw connections between light passing through the milky water and the colors seen in the sky on Earth, sunsets, nebulae, and stars viewed through lots of ISM. Be sure to make clear that the red color seen in nebulae is *not* reddening. That is red light emitted by the gas itself whereas the blue color is light reflected by nearby stars. The color of the stars themselves is reddened from their normal color due to their light passing through the ISM.

What is the difference between Heat and Temperature?

The **Heat** of a substance is the sum total of the energy of all the particles within it. The **Temperature** is a measure of the average energy of each particle. The rate of transfer of heat from one substance (or system of particles) to another depends upon the density of the substances. A substance may have a very high temperature but such a low density that it transfers heat very slowly. The ISM in the Local Bubble is an example of a very hot gas with little heat. Have students carry out the following experiments to explore the difference between Heat and Temperature. These experiments may be done at home or in the classroom. Drinking glasses can be used at home instead of glass beakers. To make this a more inquiry-oriented activity have students conduct these experiments before the classroom discussion of the difference between Heat and Temperature and the ISM.

1) Set an oven to 400° F (478 K, 204°C). Allow it time to reach the desired temperature. Use an oven thermometer if you can to verify the temperature inside the oven.
2) Gather several identical ice cubes. Place one ice cube in the oven (in an oven safe glass) and time with a stopwatch how long it takes for the cube to completely melt. Repeat 5 times and calculate the average amount of time it takes an ice cube to melt in an oven at 400° F.
3) Prepare a pot of boiling water on the stovetop. At standard sea level pressure water boils at 212°F (373 K, 100°C).
4) Carefully drop an ice cube in the boiling water and time how long it takes for the ice cube to completely melt. Repeat 5 times and again calculate the average length of time it takes for an ice cube to melt in water at 212° F.
5) In which substance does the ice cube melt faster? Which substance has a higher temperature? Which substance has a higher density, water or air?
6) Now gather two identical glasses. Fill one with water. Let the two glasses sit side by side for a while. Using a thermometer in each glass measure the temperatures.
7) When the temperature of the water and the air in the empty glass are the same drop an identical ice cube in each at the same time. Time how long it takes for each ice cube to completely melt. Repeat the experiment 5 times and calculate the average times for each glass.
8) In which glass did the ice melt fastest? In which substance is heat flow faster, water or air? Does this make sense given that they were both at the same temperature? Why?
9) If you were an astronaut in a space ship out in the Local Bubble, would your hand heat up if you stuck it outside the spacecraft unprotected? Why or why not? (Ask this question after a classroom discussion about the ISM.)

Answers to Problems

1a) The volume of the Andromeda galaxy is calculated like a disk (cylinder): area of a circle times the height: $V = \pi r^2 h$

$= \pi \times (135{,}000 \text{ light-years}/ 2)^2 \times 1{,}000$ light-years

$= \mathbf{1.43 \times 10^{13}}$ **light-years^3**

The average number density, n, of stars is the total number of stars divided by the total volume.

$n = N/V$

$= 2 \times 10^{11}$ stars / 1.43×10^{13} light-years^3

= **0.014 stars/ light-years^3**

1b) The volume of empty space surrounding each star is the inverse of the number density.

Volume per star = 1/n = **72 light-years^3/star**

1c) The average distance between stars is the cube-root of the volume of empty space surrounding each star

$d = (1/n)^{1/3}$ = **4.2 light-years**

2) The number of particles in an empty mug on a desk is about 1,500 Quintillion (1.5 Sextillion = 1.5×10^{21}) and the average number density, n, of interstellar space is: n = 1 atom/cm^3. To calculate how much volume would contain 1.5 sextillion atoms set up a ratio.

1 atom/cm^3 = 1.5×10^{21} atoms/V

Therefore, solving for V gives:

V = 1.5×10^{21} cm^3 * (1 km /10^5 cm)^3

= 1.5×10^6 km^3 = **(114 km)^3**

Thus, the density in interstellar space is like taking a mug full of air and spreading out that air into a cubic volume that is 114 kilometers on each side.

Orders of Magnitude Key

Name	Number	Power
Decillion	1 000 000 000 000 000 000 000 000 000 000 000	10^{33}
Nonillion	1 000 000 000 000 000 000 000 000 000 000	10^{30}
Octillion	1 000 000 000 000 000 000 000 000 000	10^{27}
Septillion	1 000 000 000 000 000 000 000 000	10^{24}
Sextillion	1 000 000 000 000 000 000 000	10^{21}
Quintillion	1 000 000 000 000 000 000	10^{18}
Quadrillion	1 000 000 000 000 000	10^{15}
Trillion	1 000 000 000 000	10^{12}
Billion	1 000 000 000	10^{9}
Million	1 000 000	10^{6}
Thousand	1 000	10^{3}
Hundred	100	10^{2}
Ten	10	10^{1}
One	1	10^{0}
Tenth	0.1	10^{-1}
Hundredth	0.01	10^{-2}
Thousandth	0.001	10^{-3}
Millionth	0.000 001	10^{-6}
Billionth	0.000 000 001	10^{-9}
Trillionth	0.000 000 000 001	10^{-12}
Quadrillionth	0.000 000 000 000 001	10^{-15}
Quintillionth	0.000 000 000 000 000 001	10^{-18}
Sextillionth	0.000 000 000 000 000 000 001	10^{-21}
Septillionth	0.000 000 000 000 000 000 000 001	10^{-24}
Octillionth	0.000 000 000 000 000 000 000 000 001	10^{-27}
Nonillionth	0.000 000 000 000 000 000 000 000 000 001	10^{-30}
Decillionth	0.000 000 000 000 000 000 000 000 000 000 001	10^{-33}

Glossary

Angstrom (Å): A unit of length equal to 10^{-10} m.
Astrophysics: The part of astronomy dealing with the physics and chemistry of astronomical objects and events.
Atom: The smallest particle of an element that exhibits the chemical properties of the element.
AU: Abbreviation for "astronomical unit," the distance between the Earth and Sun (about 93 million miles)(semi-major axis of the orbit of Earth = 1AU)
Bok Globules: dark clouds of dust and gas that are typically condensing to form stars, named after astronomer Bart Bok who studied them.
CHIPS: Cosmic Hot Interstellar Plasma Spectrometer
Density: The ratio of the mass of an object to its volume. d = m/V
Diffuse: Widely spread or scattered; not concentrated.
Electromagnetic Radiation: A broad band of energy that consists of radio waves, microwaves, infrared rays, visible light, ultraviolet rays, extreme ultraviolet rays, X-rays, and gamma rays.
Electromagnetic Spectrum: The range of all wavelengths of radiation.
Electron: A very lightweight, negatively charged part of an atom.
Element: A substance that is made of atoms with the same chemical properties, and which cannot be decomposed chemically into simpler substances.
Extinction: Dimming of light (attenuation) from a celestial body produced by the Earth's atmosphere or by interstellar material.
Interstellar: Located between or among the stars
Interstellar Dust: Microscopic solid grains, composed largely of common materials such as graphite, silicates.
Interstellar Gas: Sparse gas in interstellar space.
Interstellar Medium or ISM: All the gas and dust found between stars.
Interstellar reddening: The interstellar dust scatters blue light more effectively than red light - which means that most of the light that reaches us through the interstellar dust is reddish.
Ion: An atom that has become electrically charged by the addition or loss of one or more electrons.
Ionized gas: A gas that has been ionized so that it contains free electrons and charged particles.
Light Year: The distance that light can travel one year in a vacuum, which is about 5.8 trillion miles or 9.5 trillion kilometers.
Local Bubble: A hot, low density region containing the Sun and thousands of other nearby stars.
Molecule: A combination of two or more atoms bound together electrically; the smallest part of a compound that has the properties of that substance.
Nebula: Latin word meaning *cloud*. A place in the ISM with a larger density than average.
Orion Nebula: A hot cloud of ionized gas that is a nearby region of recent star formation, located in the sword of the constellation of Orion.
Parsec: A unit of distance equal to 3.26 light years; 3.09×10^{13} km or 1.92×10^{13} miles. A parsec is the distance at which the radius of the Earth's orbit subtends an angle of one second of arc.
Plasma: A fourth state of matter - not a solid, liquid, or gas. In a plasma, the electrons are pulled free from the atoms and can move independently. The individual atoms are charged, even though the total number of positive and negative charges is equal, maintaining an overall electrical neutrality.
Spectrometer: An instrument for examining recorded and measured **electromagnetic spectra**.
Scattering: The change in the paths of photons without absorption or change in wavelength.
Supernova Remnant: The remains of a gigantic explosion marking the end of the life of either a massive star or a white dwarf accumulating mass from a neighbor.
Temperature: A measure of the average of random speeds of the microscopic particles in matter.
Ultraviolet: A type of electromagnetic radiation that is invisible and beyond the violet part of the visible spectrum of light. It has shorter wavelengths (100 – 4000 Å) and carries higher energy than visible light.

Resources

- CHIPS Education and Public Outreach website (including more lessons on the Local Bubble and the concepts of density, heat, and temperature): **http://cse.ssl.berkeley.edu/chips_epo/**
- Structure and Evolution of the Universe Education Forum: **http://cfa-www.harvard.edu/seuforum/**
- Center for Science Education @ Space Sciences Laboratory: **http://cse.ssl.berkeley.edu/**
- Online ISM Tutorial from UNH: **http://www-ssg.sr.unh.edu/tof/Outreach/Interstellar/index.html**
- For good middle school lessons on density see the LHS GEMS guide entitled *Discovering Density*. (**http://www.lhsgems.org**)

Image References

0. Mosaic of the Milky Way. Credit & Copyright: Axel Mellinger
1. Orion Nebula. Taken with HST/WFPC2. Image courtesy of NASA.
2. Horsehead Nebula. Taken with VLT. Image courtesy of ESO.
3. The Trifid Nebula. Image courtesy of Todd Boroson/NOAO/AURA/NSF.
4. NGC 4603. Taken with HST/WFPC2. Image courtesy of NASA.
5. The Crab Nebula. Taken with VLT. Image courtesy of ESO.
6. N70 in the LMC. Taken with VLT. Image courtesy of ESO.