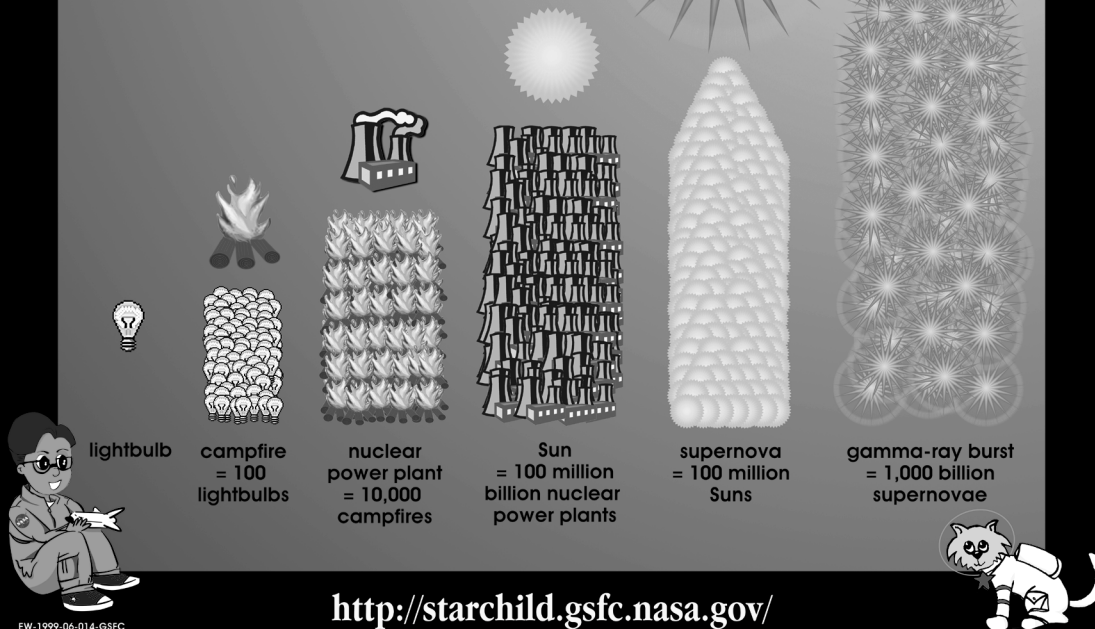


GAMMA-RAY BURSTS

*... the most energetic
events in the
Universe!*



An Information & Activity Booklet Grades 5-8 1999-2000

StarChild - a Learning Center for Young Astronomers

STARCHILD presents...



GAMMA-RAY BURSTS

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This booklet, along with its matching poster, is meant to be used in conjunction with the *StarChild* Web site or CD-ROM.

<http://starchild.gsfc.nasa.gov/>

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National Mathematics and Science Content Standards for the Activities in this Booklet

All Standards are for Grades 5-8

NSES

• A Timely Matter

Standard A: Science as Inquiry

NCTM

Standard 1: Problem Solving
Standard 2: Communication
Standard 4: Connections
Standard 5: Numbers &
Number Relation
Standard 7: Computation &
Estimation

• Electromagnetic Notation

Standard A: Science as Inquiry

Standard B: Physical Science

Standard 1: Problem Solving
Standard 2: Communication
Standard 3: Reasoning
Standard 4: Connections
Standard 5: Numbers &
Number Relation
Standard 6: Number Systems
& Theory
Standard 7: Computation &
Estimation
Standard 8: Patterns & Functions

• Telescopic Trivia

Standard A: Science as Inquiry

Standard E: Science & Technology

Standard G: History & Nature of Science

Standard 4: Connections
Standard 13: Measurement

• From Billions to Nonillions

Standard A: Science as Inquiry

Standard 1: Problem Solving
Standard 2: Communication
Standard 3: Reasoning
Standard 4: Connections
Standard 5: Number &
Number Relation
Standard 6: Number Systems
& Theory
Standard 8: Patterns & Functions

• High-Energy Word Search

Standard A: Science as Inquiry
Standard B: Physical Science
Standard G: History & Nature of Science

Standard 1: Problem Solving
Standard 4: Connections

• Cosmic Code

Standard A: Science as Inquiry
Standard E: Science & Technology

Standard 1: Problem Solving
Standard 2: Communication
Standard 3: Reasoning
Standard 4: Connections
Standard 5: Numbers &
Number Relation
Standard 6: Number Systems
& Theory
Standard 8: Patterns & Functions

• Gamma Grams

Standard 1: Problem Solving
Standard 3: Reasoning
Standard 4: Connections

• Start Your Engines!

Standard A: Science as Inquiry
Standard E: Science & Technology
Standard F: Science in Personal
& Social Perspective
Standard G: History of Science

Standard 1: Problem Solving
Standard 3: Reasoning
Standard 4: Connections
Standard 10: Statistics

• Instrumental Matches

Standard E: Science & Technology
Standard G: History of Science

Standard 1: Problem Solving
Standard 4: Reasoning
Standard 4: Connections

• Gamma-Ray Words

Standard A: Science as Inquiry
Standard G: History of Science

Standard 1: Problem Solving
Standard 3: Reasoning

Preface

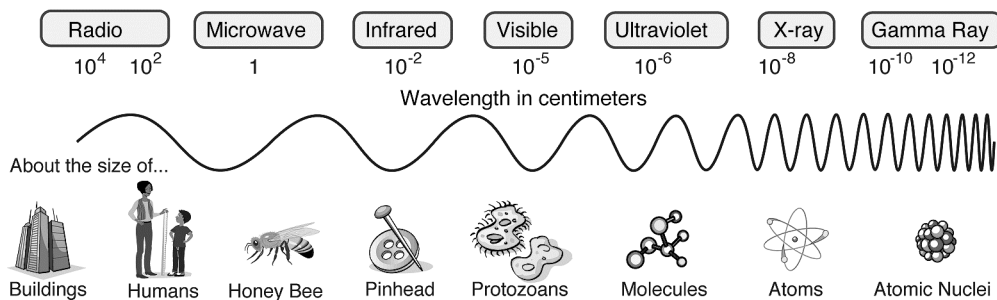
WELCOME to the third in a series of posters and activity booklets produced in conjunction with the *StarChild* Web site. The poster/booklet sets are intended to provide additional curriculum support materials for some of the subjects presented in the Web site. The information provided for the educator in the booklet is meant to give the necessary background information so that the topic can be taught confidently to students. The activities can be used to engage and excite students about the topic of gamma-ray bursts in a number of disciplines and ways. All activities can be photocopied and distributed for educational, non-commercial purposes!

For additional materials and information, visit the *StarChild* Web site at <http://starchild.gsfc.nasa.gov/>. We also look forward to hearing your opinions about this poster/booklet set! Our email address is starchild@heasarc.gsfc.nasa.gov.

Gamma-Ray Bursts

What causes gamma-ray bursts? The first burst was detected over 30 years ago and the mystery that surrounds their origin continues to exist. We do know that gamma-ray bursts are the most energetic events to occur in the Universe!

In order to understand what a gamma-ray burst (or GRB) is, you must first realize that gamma-rays are a type of light. In fact, gamma-rays are the most energetic form of light known. Light is a form of energy called electromagnetic radiation. Electromagnetic radiation comes in tiny packets of energy called photons. Photons come in a wide range of energies. Electromagnetic radiation can be placed in an arrangement according to the energy amount of the photons. This orderly arrangement is known as the electromagnetic spectrum.



At the low-energy end of the spectrum we find radio waves. They have a very long wavelength. At the high-energy end of the spectrum we find gamma-rays. They possess a very short wavelength. For electromagnetic waves, the relationship between wavelength and energy is an inverse relationship. The shorter the wavelength, the greater the energy; the longer the wavelength, the less the energy. Humans cannot see the light forms at the low and high-energy ends of the spectrum. We can only see light that falls in the visible range of the spectrum. Visible light is in the middle of the spectrum and accounts for a very small percentage of the energy range on the whole spectrum.

If an astronomer were to study the Universe only in the visible range of the spectrum, the large majority of events would go unobserved. Cosmological events such as star birth and star death emit photons that occur across the entire electromagnetic spectrum. Thanks to considerable technological advances, astronomers now have the ability to view the Universe in radio waves, gamma-rays, and all energies in between. Distant quasars were first discovered by the radio waves they emit. Galactic dust can be observed in the infrared range while light from ordinary stars such as the Sun can be observed in the visible and ultraviolet range. Extremely hot gas can be observed by the X-rays that it emits. Observations in the gamma-ray range of the spectrum reveal a very energetic Universe. Such energetic phenomena as a blazar (which consist of a supermassive black hole with jets of particles blasting away from near the event horizon), solar flares, and the radioactive decay of atomic nuclei created in supernova explosions all produce gamma-rays.

So what exactly is a gamma-ray burst? At least once a day, the sky lights up with a spectacular flash of gamma-rays coming from deep space (remember: gamma-rays are not in the visible range of the electromagnetic spectrum so we consequently are not aware of the phenomena). The brightness of this flash of gamma-rays can temporarily overwhelm all other gamma-ray sources in the Universe. The burst can last from a fraction of a second to over a thousand seconds. The time that the burst occurs and the direction from which it will come cannot be predicted. Currently, the exact cause of these flashes is unknown. Gamma-ray bursts can release more energy in 10 seconds than the Sun will emit in its entire 10 billion-year lifetime. So far, it appears that all of the bursts we have observed have come from outside the Milky Way Galaxy. Scientists believe that a gamma-ray burst will occur once every few million years here in the Milky Way, and in fact may occur once every several hundred million years within a few thousand light-years of Earth.

The first gamma-ray bursts were detected while scientists were looking for violations of the Nuclear Test Ban Treaty during the Cold War Era of the 1960s. Several satellites employed to monitor treaty compliance detected a large increase in the number of gamma-rays they counted each second. It was determined that the gamma-rays were coming from outer space and not from a nuclear bomb exploding in the Earth's atmosphere. Although Ray Klebesadel and his colleagues at the Los Alamos National Laboratory in New Mexico found these bursts in data going back to 1967, their discovery was not reported to the world until 1973.

There are several theories currently discussed as possible causes of gamma-ray bursts. One explanation proposes that they are the result of colliding neutron stars. Neutron stars are the corpses of massive stars (5 to 10 times the mass of our Sun) that have come to the ends of their lifecycles. They are extremely dense. Although their diameter may only be 20 kilometers, their mass is about 1.4 times that of the Sun. A second theory proposes that gamma-ray bursts are the result of a merging between a neutron star and a black hole or between two black holes. Black holes result when supermassive (greater than 20 times the mass of our Sun) stars die. A new theory that is attracting considerable attention states that gamma-ray bursts occur as the result of material shooting towards Earth at almost the speed of light as the result of a hypernova. A hypernova explosion can occur when the largest of the supermassive stars come to the end of their lives and collapse to form black holes. Hypernova explosions can be at least 100 times more powerful than supernova explosions.

By solving the mystery of gamma-ray bursts, scientists hope to gain further knowledge of the origins of the Universe, the rate at which the Universe is expanding, and the size of the Universe. Satellites such as NASA's Compton Gamma-Ray Observatory and Hubble Space Telescope, and ESA's BeppoSAX have given us valuable data in our quest to solve the mystery of GRBs. These satellites have limitations, however. One of them is that once a burst is detected, it takes too long to reposition the satellite in order to face the burst and collect data. They are also limited as to the range of the electromagnetic spectrum in which they can make observations. Recently, scientists were able to observe an optical counterpart to a burst as the burst was occurring. This extraordinary event occurred as the result of a great deal of planning, cooperation, and luck. On January 23, 1999, a network of scientists was notified within 4 seconds of the start of a burst that a

burst was in progress. Thanks to the Compton Gamma-Ray Observatory, BeppoSAX, the Internet, and a special robotic ground-based telescope, scientists were able to monitor the burst from start to finish at multiple wavelengths. It had the optical brightness of 10 million billion Suns, which was only one-thousandth of its gamma-ray brightness!

The future looks good for solving the mystery of GRBs. A satellite called the High Energy Transient Explorer (HETE) will be launched in late 1999 or early 2000. Its prime objective is to carry out a study of gamma-ray bursts with X-ray and gamma-ray instruments. The original HETE was lost due to a launch failure in 1996. The new high-energy explorer is a similar satellite called HETE-2. Swift, a satellite with the capacity to study the Universe in a multitude of wavelengths, has been proposed for launch in approximately 2003. The satellite is aptly named because once a burst is detected, it can be repositioned to face the gamma ray source within 50 seconds. Through being able to simultaneously observe the burst in the optical, ultraviolet, X-ray, and gamma-ray ranges of the electromagnetic spectrum, scientists hope to answer the many questions surrounding gamma-ray bursts. In approximately 2005, the Gamma-Ray Large Area Space Telescope (GLAST) will also be launched and should provide scientists with additional insight into the gamma-ray burst mystery.

A TIMELY MATTER

Very large numbers are commonly used to describe the distances between objects and the sizes of bodies in the Universe. It's difficult to visualize quantities expressed as millions, billions and trillions because we don't have much practice in using such large numbers in the course of everyday life. The following activity will give you practice in using large numbers as you convert back and forth between two familiar units of time.

When you compute answers for this activity, the number of hours in a day is exactly 24 and the number of days in a year can be rounded to exactly 365. All computations should be based on one year consisting of 8,760 hours. (24 hours x 365 days = 8,760 hours)

Hint: Use reference tools such as *StarChild* to find unknown historical dates.

ANSWER THE FOLLOWING QUESTIONS:

1. What is your age in hours? _____
2. If you live to be one hundred years of age, how many hours will you have lived?

3. To the nearest whole year, how many years would you have to live to reach the age of 1 million hours? _____
4. The oldest person who ever lived was Jeanne Louise Calment. She was born on February 21, 1875 and died at the age of 122 on August 4, 1997. How many hours had she lived? _____ (assume that birth and death took place at the same time of day)
5. "King's Holly", a plant found in Tasmania, is believed to be 40,000 years old. How many hours of age does this represent?
6. In what year would an event that happened 2 million hours ago have occurred? _____

Assume that each of the following historical events occurred on today's date. Look at the year or historical time in which each occurred, then determine how many hours ago each event took place.

7. Chewing gum was invented in the United States in 1848.
8. William Herschel discovered Uranus in 1781.
9. The pressure cooker was invented in France in 1679.
10. The Great Wall of China, incorrectly said to be the only man-made object visible from the Moon, was completed 2,174 years before man set foot on the Moon.

11. The Minoans invented the flush toilet 3,493 years before Columbus set sail for the “New World”.

12. The first Olympian Games (which evolved into the Olympic Games) were held 2,745 years before Jocelyn Bell Burnell discovered pulsars.

Challenge: Name an event that took place one billion or more hours ago. Cite your references and show all of your computations.

ELECTROMAGNETIC NOTATION

Scientific notation is used when dealing with very large numbers such as 43,000,000 or very small numbers such as .000043. Scientific notation allows us to write these numbers and work with these numbers without the cumbersome job of dealing with so many digits. In scientific notation, forty-three million becomes 4.3×10^7 simply by moving the decimal 7 places to the left. Numbers less than one require the decimal to be moved to the right so forty-three millionths becomes 4.3×10^{-5} . Notice the exponent is negative when the decimal is moved to the right while the exponent is positive when the decimal is moved to the left. Remember that with scientific notation only one digit should be in front of the decimal.

The electromagnetic spectrum is an arrangement of electromagnetic radiation according to wavelength, frequency, or energy level. The spectrum ranges from radio waves, which are low-energy, low-frequency, long waves, to gamma-rays, which are the high-energy, high-frequency, short waves. Listed in order below are the components of the electromagnetic spectrum. Beside each type of radiation you will find the length of a wave in meters which falls into that radiation type. A wavelength is the distance from one crest or trough to the next crest or trough. Convert these numbers to scientific notation by moving the decimal to the left or the right.

1. gamma-rays .0000000000001 m

2. X-rays .0000000001 m

3. ultraviolet rays .00000001 m

4. visible light .0000005 m

5. infrared rays .00001 m

6. microwaves .01 m

7. radio waves 1,000 m

The number of waves that pass a particular point in a given amount of time is the wave frequency. Each component of the electromagnetic spectrum has its own frequency range. The unit on a wave's frequency is a Hertz, or wave per second. Listed below are the components of the electromagnetic spectrum. Beside each type of radiation is a frequency value expressed in scientific notation which falls in the range of that radiation type. Convert the scientific notation into standard form by moving the decimal the appropriate number of places to the left or the right.

8. gamma-rays 1×10^{21} Hertz

9. X-rays 1×10^{18} Hertz

10. ultraviolet rays 1×10^{16} Hertz

11. visible light 5×10^{14} Hertz

12. infrared rays 1×10^{13} Hertz

13. microwaves 1×10^{10} Hertz

14. radio waves 1×10^5 Hertz

TELESCOPIC TRIVIA

From the time that Galileo first used a telescope to study the heavens, these tools have been essential to our study of the Universe. Use your knowledge of telescopes, reference materials (almanacs, encyclopedia, Web searches, *Guinness Book of World Records*), as well as clues provided by the trivia information to match the telescope description in column A with its name in column B. Write the letter of the correct name from column B on the line following the Column A description.

Column A

1. The world's most powerful optical reflector telescope has a primary mirror composed of 36 hexagonal segments each 1.8m in size. Theoretically, it would be able to separate a car's headlights at a distance of 25,000 km. _____

2. This is the world's largest optical instrument for solar research; its primary mirror is 2.1 meters in diameter. _____

3. The largest metal-mirror reflector is the 1.83m reflector set up by the third Earl of Rosse in 1845. _____

4. One of the world's most powerful radio telescopes consists of 27 separate mobile antennas each 25m in diameter. The antennas are situated along a Y-shape, with each arm of the "Y" up to 20.97km long. _____

5. The world's largest planetarium can seat 300 people. Its 30m-diameter dome can project over 25,00 stars at a time. _____

6. It weighs 850 tons and has a 6-m diameter reflector. Until late 1998, it was the largest single mirror telescope in use. _____

7. This 305m-diameter single dish radio telescope is used by Project Phoenix to conduct the world's most comprehensive search for extraterrestrial intelligence. _____

8. This 2 billion-dollar instrument is the most complex and sensitive space observatory ever built. It weighs 11,000kg and standing upright would look like a 5 story building. _____

9. This was the first of twin 8-m telescopes that together can explore the entire northern and southern skies in optical and infrared light. It was built by an international partnership of eight nations. _____

10. The largest radio installation includes dishes on two continents as well as a satellite link. It is equivalent to a radio telescope with a diameter of 27,584km. _____

Column B

A. The Australia Telescope, Parkes, Siding Spring and Culgoora, Australia; Usuda and Kashima, Japan; the HALCA satellite

B. The VLA (Very Large Array) near Socorro, N.M.

C. Arecibo Radio Telescope, Arecibo, Puerto Rico

D. Gemini North Telescope, Mauna Kea, HI

E. Special Astrophysical Observatory, Zelenchukskaya, Russia

F. The W. M. Keck Telescope, Mauna Kea, HI

G. Ehime Prefectural Science Museum; Niihama City, Japan

H. Edwin P. Hubble Space Telescope

I. McMath-Pierce Solar Telescope; Kitt Peak, AZ

J. Birr Castle Telescope; County Offaly, Ireland

FROM BILLIONS TO NONILLIONS

Very large numbers are commonly used in describing objects and distances in our Universe. It's easy to correctly read even the largest numbers if you know the meanings of the prefixes that come before the "illion" in each of them. Most of the prefixes and their meanings are probably familiar to you because they are present in common words that we use and hear every day. Review the prefixes in the chart below, and then prepare to find the answer to the question that follows.

- (two) billion - 1,000,000,000
- (three) trillion - 1,000,000,000,000
- (four) quadrillion - 1,000,000,000,000,000
- (five) quintillion - 1,000,000,000,000,000,000
- (six) sextillion - 1,000,000,000,000,000,000,000
- (seven) septillion - 1,000,000,000,000,000,000,000,000
- (eight) octillion - 1,000,000,000,000,000,000,000,000,000
- (nine) nonillion - 1,000,000,000,000,000,000,000,000,000,000

I am the farthest object visible with the naked eye from Earth. I am a rotating spiral nebula located about 2.3 million light-years away. I contain over 300 billion stars. Because I am visible to the naked eye, I appeared on star charts long before the invention of the telescope. What is my name?

IN ANDROMEDA

Determine the place values in the numeral below. As you answer the following questions you will notice that each digit has a letter with which it corresponds. Below the questions, you will see a numerical message. Convert each digit in the message to its corresponding letter. If you correctly answer each question, you will know the name to place in the blank above.

578,593,018,962,345,783,278,479,218,078,469

1. What number is in the ten septillion's place? _____ = G
2. What number is in the hundred million's place? _____ = H
3. What number is in the ten trillion's place? _____ = T
4. What number is in the ten octillion's place? _____ = R
5. What number is in the hundred billion's place? _____ = E
6. What number is in the quadrillion's place? _____ = A
7. What number is in the hundred septillion's place? _____ = L
8. What number is in the hundred octillion's place? _____ = X
9. What number is in the nonillion's place? _____ = Y

MESSAGE: 7—2—4—1—9—4—3—7—1—3—0—3—5—8

HIGH-ENERGY WORD SEARCH

K L E B E S A D E L W E S U N Y U G
A D L S L F G T Y U I K L M N F Z L
Q W E A Z A C F R T H G J N Y T W A
P O C I U Y C R F V B N H S A W Q S
A S T D F V B K S W I F T T W E N T
M D R F G T U O H A S E C V A T H J
E F O V B R Q S F O H J L A V Z X C
F G M Z S E A Q Y S L A X C O V G U
B L A Z A R T E F G H E J K N L M S
A D G F T U I O Y I R E S D R A Y S
D F N G J N C S W T Q E A D E C A C
D E E P S P A C E S H R N T P Y W U
M H T T R E W D L C R G T E Y H Y J
W E I C G H K M B A E R I C H B K Q
A S C E F G B H B Q S C V L B G L N
Q W S P E C T R U M S D N F W Y I K
R A D I O S D F H W N K V X B Y M H

Use the hints below to help you locate the gamma-ray related words hidden in the above puzzle. The words may go up, down, diagonally, or at right angles to each other. The blanks located with each hint tell you the total number of words contained by the correct answer.

1. This unit of measurement is necessary because of the enormous distances that exist between objects in the Universe. _____
2. Gamma-rays are the most energetic form of this type of energy. _____
3. This body is the most consistent emitter of gamma-rays in our solar system. _____
4. This scientist was one of the first to detect a gamma-ray burst. _____

5. One theory on the origin of a gamma-ray burst states that it is the result of a merging of neutron stars or _____.
6. A space-based optical telescope that has been helpful in collecting data on gamma-ray bursts is _____.
7. An orderly arrangement of light according to its wavelength is called the _____.
8. The abbreviation for Gamma-Ray Large Area Space Telescope. _____
9. The name of the galaxy in which our solar system resides. _____
10. Gamma-rays and X-rays are found at this end of the electromagnetic spectrum.

11. Some scientists believe that gamma-ray bursts arise from the collapse of a supermassive star directly into a black hole in an event known as a _____.
12. At one end of the electromagnetic spectrum you find gamma-rays, while at the opposite end of the spectrum you find this type of wave. _____
13. The majority of the gamma-ray bursts detected come from what part of the Universe?

14. This satellite is proposed for launched in approximately 2003 and will have the ability to study gamma-ray bursts in a variety of wavelengths. _____
15. This object consists of a supermassive black hole which emits an intense beam of particles and light over a broad frequency range from radio waves to gamma-rays.

COSMIC CODE

Computers are essential tools in the efforts to collect and analyze new data about gamma-ray bursts. The language that a computer speaks is binary numbers. When you type the letters d-o-g on the keyboard the computer does not see a d, an o, or a g. The computer interprets it as a series of ones and zeroes. Binary numbers are based on the base-2 system as opposed to the base-10 system with which we work on a daily basis. Units in the base-10 system are labeled ones, tens, hundreds, thousands, etc. Base-2 units are labeled one, two, four, eight, sixteen, etc. Look at the chart below. The base-10 numbers 8, 28, 50, and 129 have been written in base-2 for you.

	512 (2 ⁹)	256 (2 ⁸)	128 (2 ⁷)	64 (2 ⁶)	32 (2 ⁵)	16 (2 ⁴)	8 (2 ³)	4 (2 ²)	2 (2 ¹)	1 (2 ⁰)
8	0	0	0	0	0	0	1	0	0	0
28	0	0	0	0	0	1	1	1	0	0
50	0	0	0	0	1	1	0	0	1	0
129	0	0	1	0	0	0	0	0	0	1

The next column in the chart would be the units 1024, then 2048, then 4096, and so on.

Below is a coded message. Use the decoder to crack the binary code and translate the gamma-ray fact. The message is displayed from left to right horizontally. Here is an example of how to use the decoder:

$$000100 = 4 = d$$

$$001111 = 15 = o$$

$$000111 = 7 = g$$

Divide the class into groups. Cut the message into horizontal strips and distribute one strip to each group. Have each group decode their part of the message. Once they have decoded their strip, have them place their work on the board. The pieces of the decoded message must then be put in the proper order to reveal the gamma-ray fact.

COSMIC CODE MESSAGE DECODER

1 = A	18 = R
2 = B	19 = S
3 = C	20 = T
4 = D	21 = U
5 = E	22 = V
6 = F	23 = W
7 = G	24 = X
8 = H	25 = Y
9 = I	26 = Z
10 = J	27 = 1
11 = K	28 = 2
12 = L	29 = 3
13 = M	30 = 4
14 = N	31 = 5
15 = O	32 = .
16 = P	33 = ,
17 = Q	34 = !

COSMIC CODE MESSAGE

000111	000001	001101	001101	000001	010010
000001	011001	010011	000001	010010	000101
010100	001000	000101	001101	001111	010011
010100	000101	001110	000101	010010	000111
000101	010100	001001	000011	000110	001111
010010	001101	001111	000110	001100	001001
000111	001000	010100	001001	001110	010100
001000	000101	010101	001110	001001	010110
000101	010010	010011	000101	100010	000111
000001	001101	001101	000001	010010	000001
011001	000010	10101	010010	010011	010100
010011	010111	000101	010010	000101	000110
001001	010010	010011	010100	000100	001001
010011	000011	001111	010110	000101	010010
000101	000100	000010	011001	000001	000011
000011	001001	000100	000101	001110	010100
100000					

GAMMA-GRAMS

In the list below you will find terms commonly associated with the study of gamma-ray bursts. Beside each term you will find instructions. Follow the instructions to form a not-necessarily-scientific anagram of the designated term. You may change the order of the letters in the newly formed word. Here is an example: ray (add a d) - yard.

1. light (add a c)
2. energy (add a c)
3. burst (drop a b)
4. emit (add a s)
5. space (add a r)
6. swift (drop the w)
7. sun (add a b)
8. radio (drop the i)
9. wave (add an e)
10. gamma (drop the g)
11. wave (drop the v)
12. bright (drop the g)
13. radio (drop the o)
14. emit (drop the I)
15. sky (add an e)

START YOUR ENGINES!

Using any of the search engines available to you, look for Web sites containing the answers to the following questions. (Notice there are some suggested Web sites to help get you started.) Answer the questions in complete sentences. Record the name of the Web page that you used as a reference when answering each question.

<http://www.batse.msfc.nasa.gov>

<http://hubcap.clemson.edu/~ggwilli/LOTIS>

<http://130.167.1.50/pubinfo/pr/1997/20/PR.html>

<http://www.batse.com/oldnews.html>

<http://www-glast.sonoma.edu>

<http://www.astro.ssu.se/~felix/GRB.html>

http://science.nasa.gov/newhome/headlines/ast29jan99_1.htm

http://science.nasa.gov/newhome/headlines/ast26mar99_1.htm

<http://imagine.gsfc.nasa.gov>

1. What is a gamma-ray?
2. What is a gamma-ray burst?
3. What are two current theories surrounding the formation of a gamma-ray burst?
4. Find an example of a comparison between the energy released by a gamma-ray burst and the Sun.
5. On average, how many gamma-ray bursts are detected each week?
6. Who was the first to detect a gamma-ray burst?
7. What year was the first gamma-ray burst detected?
8. How was the first gamma-ray burst detected?
9. For how many years after its detection was the report of the first gamma-ray burst withheld?
10. Why are scientists having such a difficult time studying gamma-ray bursts?
11. Almost all gamma-ray bursts come from outside of our Galaxy. How often does a burst occur in our galaxy, the Milky Way?
12. Name at least two satellites that are currently involved in gamma-ray burst research.

13. On January 23, 1999, scientists were able to collect the first optical data on a gamma-ray burst while it was in progress. What technological resources were used to make this event possible?
14. Why is the name Swift appropriate for the satellite that is going to be launched in approximately 2003 in order to further study gamma-ray bursts?
15. What do the letters in the name GLAST stand for and when is the launch of this satellite scheduled to occur?
16. Locate a Web site not previously cited in this exercise. Record the URL. Create an original question from the information you find at this Web site. Your question may be incorporated into future gamma-ray Web searches.

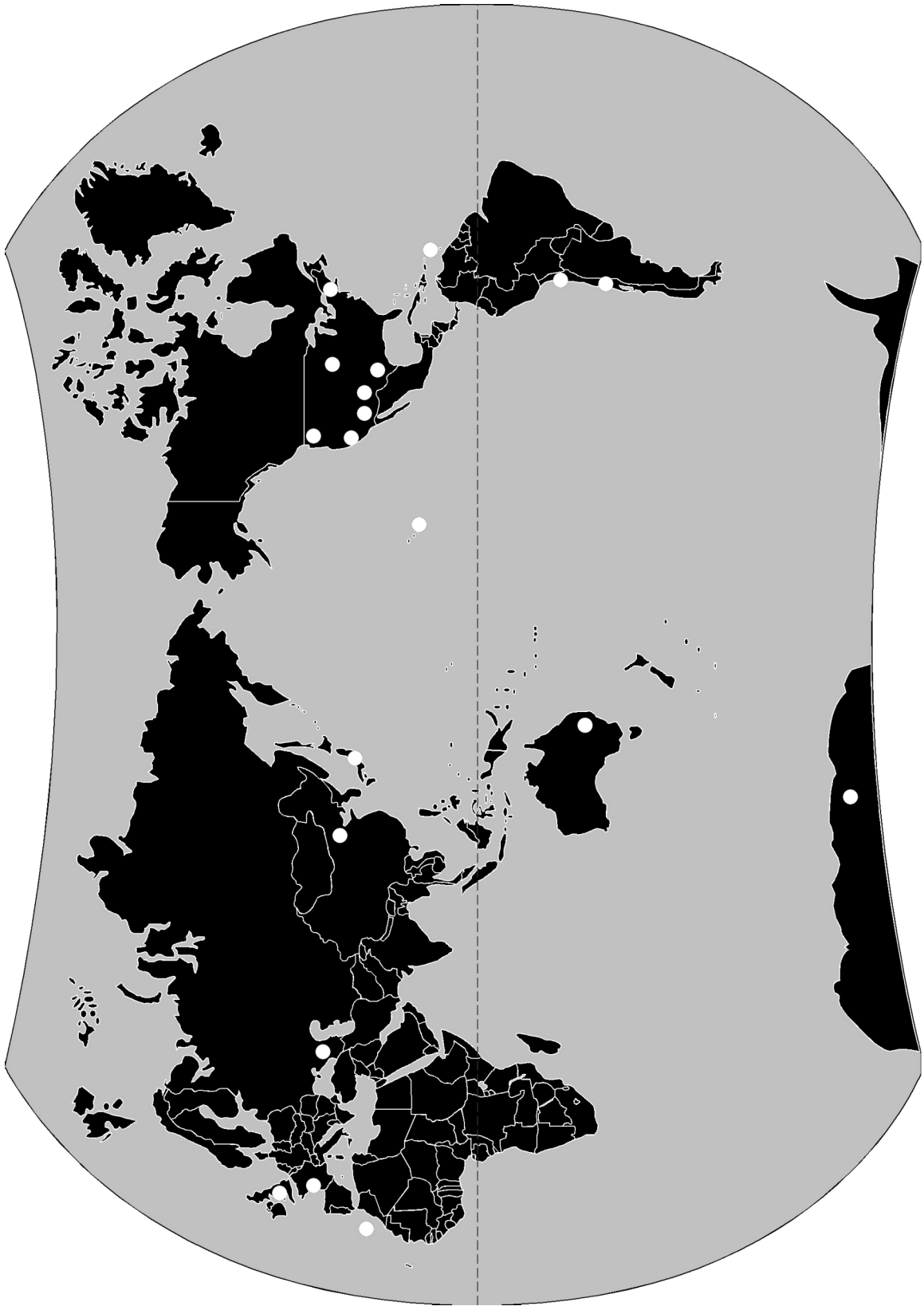
TEACHERS: Prior to starting this activity, visit all cited Web sites. Some Web sites tend to be transient while others may not be available to you on your particular server. This information needs to be discovered prior to beginning this activity.

INSTRUMENTAL MATCHES

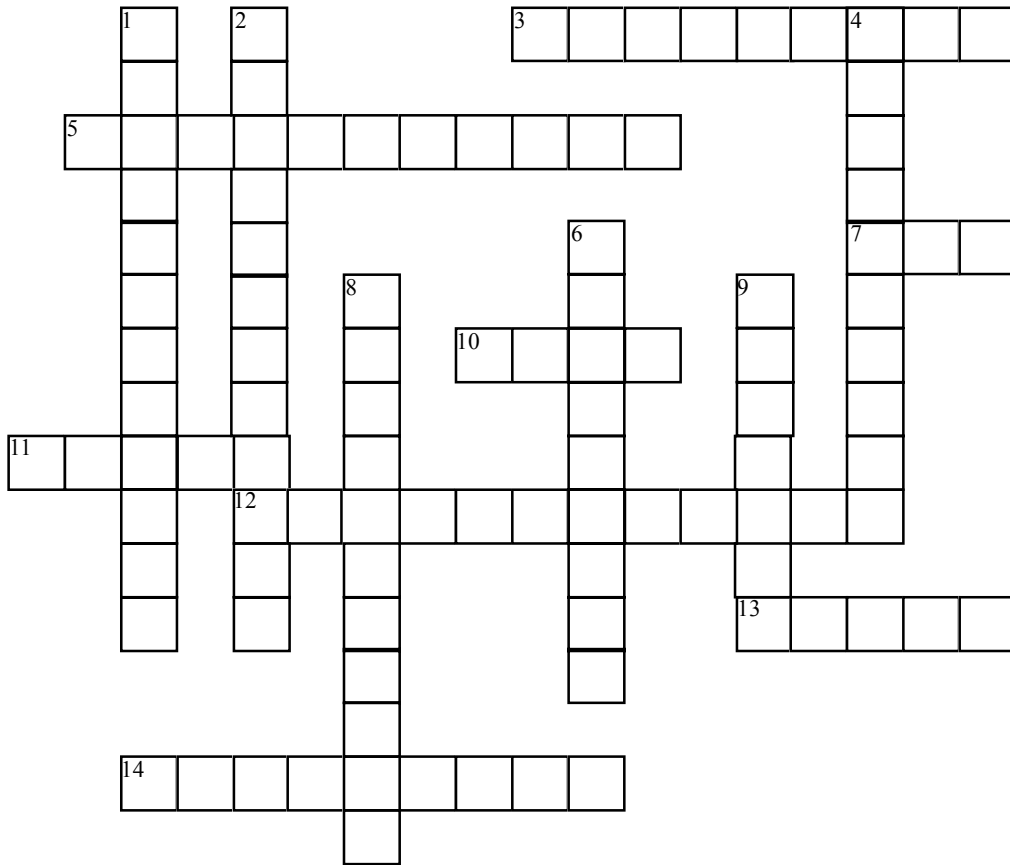
Gamma-ray bursts are one of the greatest mysteries of modern astronomy. At present, we don't know what causes them, where they come from nor when they will occur. Teams of international astronomers are working together to solve the mystery of the gamma-ray burst. The communication power of the Internet allows them to rapidly share information gathered by equipment aboard orbiting satellites and by instruments that are based on the ground. Ground based telescopes and cameras in locations around the world gather information that will help scientists find a solution to the gamma-ray burst mystery. The names and locations of several of the ground-based instruments that make up the Gamma-Ray Burst Coordinates Network (GCN) are listed below. Can you place them in their correct geographic locations? Read the geographic location of each instrument, and then carefully study the map on the following page. Use your knowledge of geography to correctly place the letter that precedes the name of each instrument in the circle at the correct map location.

- A. William Herschel Telescope, La Palma Observatory; Canary Islands
- B. The Very Large Telescope, European Southern Observatory; Paranal, Chile
- C. Very Long Baseline Array – system of ten remotely controlled radio telescopes Socorro, New Mexico
- D. Mauna Kea, Hawaii
- E. Brewster, Washington
- F. Pie Town, New Hampshire
- G. St. Croix, Virgin Islands
- H. Owens Valley, California
- I. North Liberty, Iowa
- J. Kitt Peak, Arizona
- K. Fort Davis, Texas
- L. Cerro Tololo Inter-American Observatory; Cerro Tololo, Chile
- M. Bradford Robotic Telescope; Bradford, England
- N. Beijing Observatory; Beijing, China
- O. The Automated Patrol Telescope; Siding Spring Observatory, Australia

- P. Special Astrophysical Observatory; Zelenchukskaya, Russia
- Q. Akeno Giant Air Shower Array; Akeno, Japan
- R. Antarctic Muon and Neutrino Detector Array; Antarctica
- S. Telescope a Action Rapide pour les Objects Transitoires; France



GAMMA-RAY WORDS



Across

3. unit used to measure distances in space
5. GRBs were first detected by satellites looking for _____ Ban Treaty violations
7. average number of GRBs detected daily by satellites
10. a redshift indicates movement in this direction from Earth
11. acronym for Burst and Transient Source Experiment
12. branch of astronomy dealing with behavior and physical characteristics of heavenly bodies
13. satellite planned for launch in year 2003 to study GRBs
14. optical flash and emission of X-rays occurring immediately after a GRB

Down

1. gamma-rays coming up from Earth have been detected during this severe weather occurrence
2. scientists estimate the Sun's lifetime as ten _____
4. GRBs are the most powerful _____ in the Universe
6. Cygnus X-1 is an example of one found in our Galaxy
8. an object related to a GRB which is discovered by its emission at wavelengths other than gamma-rays
9. decade in which GRBs were first discovered

ANSWER KEYS

TIMELY MATTER ANSWER KEY

These answers are true for the year 1999. Adjustments based on 8,760 hours for each ensuing year will need to be made for # 6-12.

1. answers vary (ask students to show their work)
2. 876,000 hours
3. 114 years
4. 1,072,656 hours (or 1,073,376 hours if leap years are included in calculation)
5. 350,400,000 hours
6. 1771
7. 1,322,760 hours
8. 1,909,680 hours
9. 2,803,200 hours
10. 19,307,040 hours (Neil Armstrong set foot on the moon in 1969)
11. 35,040,000 hours (Columbus sailed for the “New World” in 1492)
12. 24,317,760 hours (Jocelyn Bell Burnell discovered pulsars in 1968)

ELECTROMAGNETIC NOTATION ANSWER KEY

- | | |
|------------------------|------------------------------|
| 1. 1×10^{-13} | 8. 1,000,000,000,000,000,000 |
| 2. 1×10^{-10} | 9. 1,000,000,000,000,000,000 |
| 3. 1×10^{-8} | 10. 10,000,000,000,000,000 |
| 4. 5×10^{-7} | 11. 500,000,000,000,000 |
| 5. 1×10^{-5} | 12. 10,000,000,000,000 |
| 6. 1×10^{-2} | 13. 10,000,000,000 |
| 7. 1×10^3 | 14. 100,000 |

TELESCOPIC TRIVIA ANSWER KEY

- | | |
|------|-------|
| 1. F | 6. E |
| 2. I | 7. C |
| 3. J | 8. H |
| 4. B | 9. D |
| 5. G | 10. A |

FROM BILLIONS TO NONILLIONS ANSWER KEY

- | | | |
|----------|----------|----------|
| 1. 1 = G | 4. 9 = R | 7. 0 = L |
| 2. 2 = H | 5. 4 = E | 8. 5 = X |
| 3. 7 = T | 6. 3 = A | 9. 8 = Y |

THE GREAT GALAXY

HIGH-ENERGY WORD SEARCH ANSWER KEY

K	L	E	B	E	S	A	D	E	L			S	U	N			G
		L		L						I							L
		E			A					G							A
		C				C						H					S
		T					K	S	W	I	F	T	T				T
		R						H						A			
		O			R				O					V			
		M				A		Y		L				O			
B	L	A	Z	A	R		E		G		E			N			
		G						Y		R		S		R		Y	
		N							T		E			E		A	
D	E	E	P	S	P	A	C	E		H		N		P		W	
		T						L			G		E	Y		Y	
		I						B				I		H		K	
		C						B					L		G	L	
		S	P	E	C	T	R	U	M							I	
R	A	D	I	O				H								M	H

- | | | |
|----------------|-----------------------------|----------------|
| 1. light-year | 7. electromagnetic spectrum | 12. radio |
| 2. light | 8. GLAST | 13. deep space |
| 3. Sun | 9. Milky Way | 14. Swift |
| 4. Klebesadel | 10. high energy | 15. blazar |
| 5. black holes | 11. hypernova | |
| 6. Hubble | | |

COSMIC CODE MESSAGE

Gamma-rays are the most energetic form of light in the Universe! Gamma-ray bursts were first discovered by accident.

GAMMA-GRAMS ANSWER POSSIBILITIES

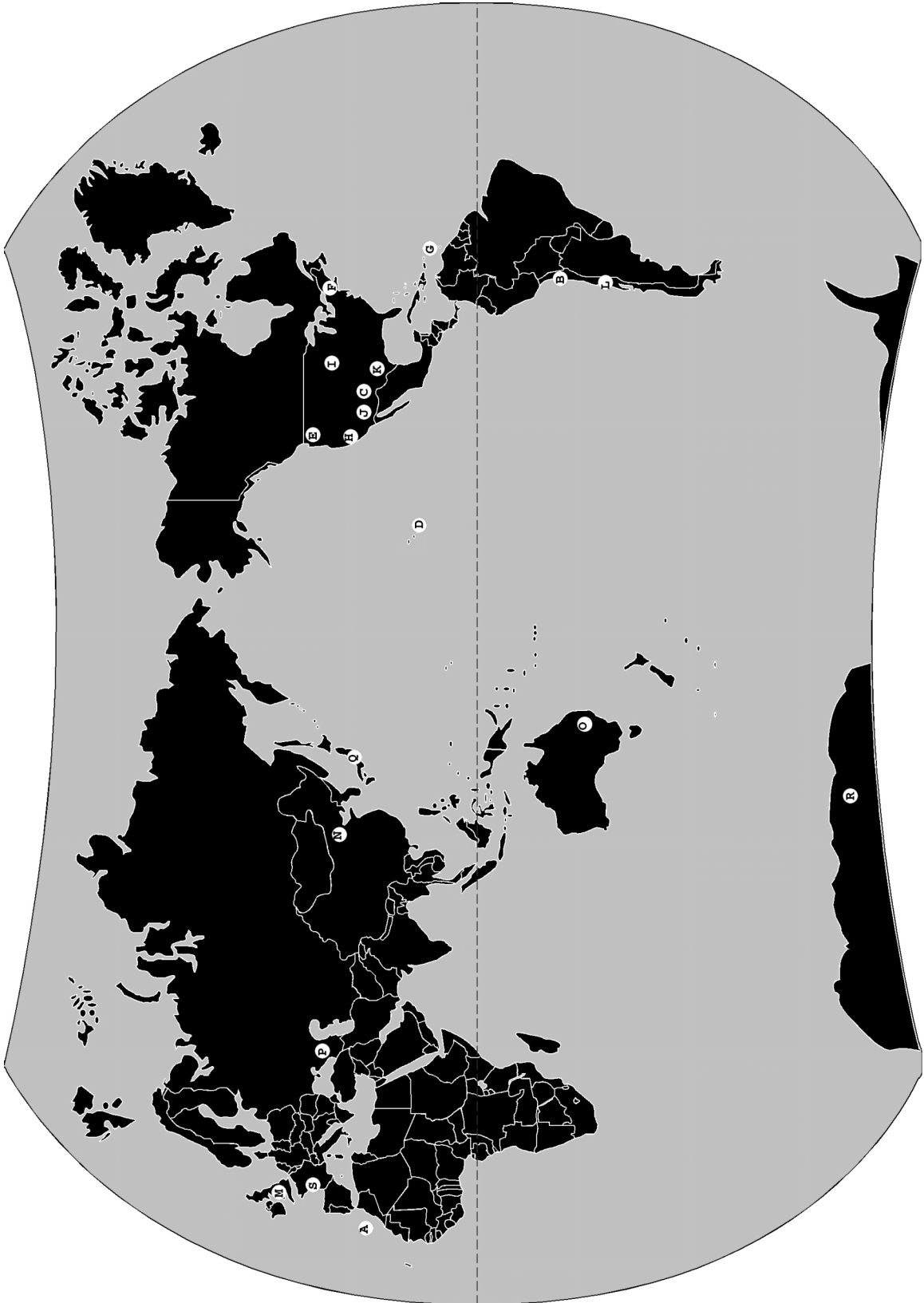
1. glitch
2. regency
3. rust
4. times
5. parsec
6. fist
7. buns
8. road
9. weave
10. mama
11. awe
12. birth
13. arid
14. met
15. keys

START YOUR ENGINES! ANSWER KEY

(Teachers: As new information is discovered, the following answers may change.)

1. A gamma-ray is a component of the electromagnetic spectrum. It is a high-energy form of light that falls outside of the range visible to the human eye. A gamma-ray has a very short wavelength but a very high frequency.
2. A gamma-ray burst is the most energetic phenomenon that is currently occurring in the Universe. At least once a day, a tremendous, concentrated flash of gamma-rays comes from a source, usually in deep space.
3. Gamma-ray burst theories currently being discussed are: merging neutron stars, merging black holes, and hypernovae.
4. Example: 1. Gamma-ray bursts release as much energy in 10 seconds as the Sun does in 10 billion years. 2. The gamma-ray burst detected on January 23, 1999 had the energy of 10 million billion Suns.
5. 7 (At least one per day)
6. Ray Klebesadel and others at Los Alamos National Laboratory in New Mexico.
7. 1967
8. The first burst was detected by satellites monitoring compliance with the Nuclear Test Ban Treaty.
9. 6 years
10. Gamma-ray bursts are unpredictable. We do not know when they will occur or in what direction they will occur. The majority of them occur in deep space, at great distances from Earth.
11. once every few million years
12. Compton Gamma-Ray Observatory, Hubble Space Telescope, BeppoSAX (a European Satellite)
13. satellites (Compton Gamma-ray Observatory, BeppoSAX, Hubble Space Telescope), the Internet, a ground-based robotic telescope
14. Swift can be positioned toward a burst within 50 seconds of it first being detected.
15. Gamma-Ray Large Area Space Telescope, 2005

INSTRUMENTAL MATCHES ANSWER KEY



ABOUT THE POSTER

One of the most amazing things about gamma-ray bursts is their enormous power. Power is defined as the amount of energy emitted per unit time. Shown on the poster is a bar graph which compares the power emitted by several different radiant objects or events. The values given represent the peak power output of each. In other words, it is a snapshot in time at the instant each object or event is emitting the greatest amount of power it will ever emit. Some things – like the light bulb – emit constant power over time. Other things like a supernova explosion or a gamma-ray burst can emit enormous amounts of power one second and thousands or hundreds of thousands of times less power the next second. By showing peak power, we allow ourselves to compare very different things like light bulbs and supernovae in a meaningful way. Simply put, we display on our graph the following information: in the one second (whenever it occurred) that they each emitted their maximum power, what was it?

It may be interesting to consider the total power emitted as well. This takes into account the amount of time that each object or event emitted energy and how much energy they emitted as a function of time. Consider this, the total power emitted by a supernova is only about a factor of 10 less than that of a gamma-ray burst. What does this tell us about the amounts of time over which these events occur?

GAMMA-RAY BURST GLOSSARY

BeppoSAX - An Italian - Dutch satellite actively involved in the quest to collect gamma-ray burst data in the X-ray range of the electromagnetic spectrum. It was named after the Italian physicist Giuseppe "Beppo" Occhialini who was instrumental in forming what is today known as the European Space Agency.

Black hole - The final stage in the lifecycle of a supermassive star. A black hole is so dense that its gravitational field prevents even photons of light from escaping

Blazar – An object which consists of a supermassive black hole that emits an intense beam of particles and light over a broad frequency range from radio waves to gamma-rays.

Compton Gamma-Ray Observatory - A NASA satellite launched in 1991. It carries four instruments designed to observe the Universe in gamma-rays. The observatory was named in honor of Dr. Arthur Holly Compton, winner of a Nobel Prize in physics.

Density - The amount of mass per unit of volume.

Electromagnetic radiation - Another term for light. Light waves are actually fluctuations of electric and magnetic fields in space.

Electromagnetic spectrum - The orderly arrangement of electromagnetic radiation. The arrangement is based on wavelength, or energy level. The longer the wavelength the lower the energy level. Starting with the longest wavelength, the order is radio wave, microwave, infrared, visible light, ultraviolet, X-ray, and gamma-ray.

ESA – European Space Agency

Gamma-ray - The highest energy electromagnetic radiation. It has a very short wavelength.

Gamma-ray burst - A sudden burst of gamma-rays coming from a source usually in deep space. The burst may last from a fraction of a second to several minutes.

Gamma Ray Large Area Space Telescope - A proposed five year high-energy gamma-ray astronomy mission scheduled for launch in 2005

Hypernova - A phenomena new to astronomy discussions. It occurs as the result of a supermassive star undergoing an explosion more power than a supernova. Almost all of the energy generated by the explosion is in the gamma-ray range of the electromagnetic spectrum. It results in the formation of a black hole.

Massive star - A star with a mass 10-15 times that of the Sun.

Neutron star - The remnant core of a massive star after a supernova explosion. It is extremely dense. Though its diameter is only about 15 kilometers, its mass is about 1.4 times that of the Sun.

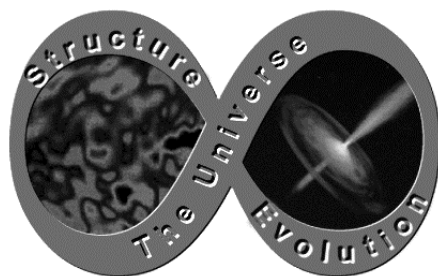
Quasar - A quasi-stellar radio source. A star-like object that is a powerful producer of radio waves.

Solar flare - A sudden, rapid and intense variation in brightness that occurs when magnetic energy built up in the solar atmosphere is suddenly released.

Supermassive star - A star with a mass at least 15 times that of the Sun.

Supernova - The explosion of a massive star. This explosion occurs in the star's death phase right after the red giant stage. At the peak of the explosion, it can outshine a galaxy.

Swift - A multiwavelength observatory for gamma-ray burst astronomy proposed for launch in 2003.



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