National Aeronautics and
Space Administration

ASTROLYMPICS

Training to See the Invisible: Science Activities

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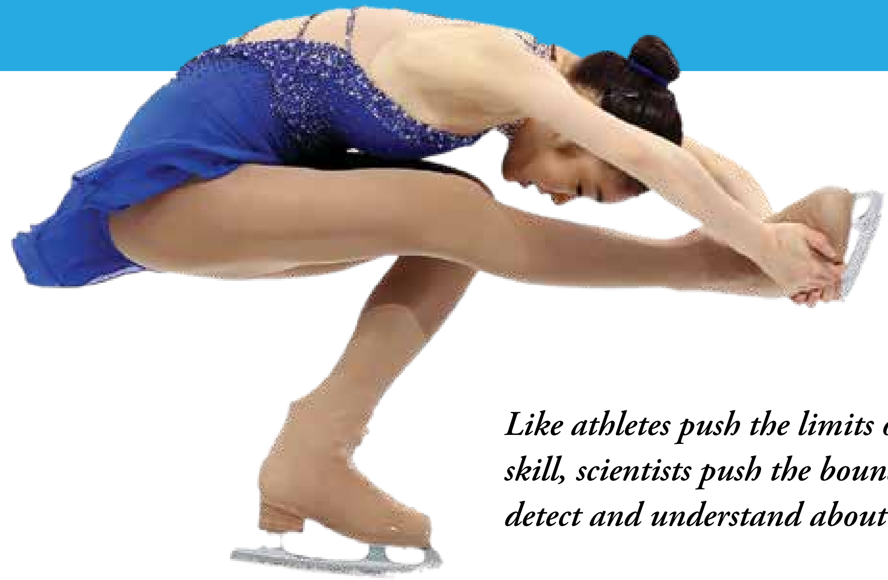

Like athletes push the limits of speed, strength, and skill, scientists push the boundaries of what we can detect and understand about our Universe.

One of the biggest challenges? Turning the invisible into something we can see. Telescopes on Earth and in space are built to capture all kinds of light — not just the visible light we see with human eyes, but also radio, infrared, ultraviolet, X-ray, and gamma ray light. Each type of light reveals something different about the cosmos, like unique events in a cosmic competition.

When telescopes detect such light, they send the data back to Earth using a global relay of antennas. This information arrives in binary code — a string of 1s and 0s — kind of like the digital stats of a sporting event. Scientists then decode this data to figure out when a particle of light arrived, how energetic it was, and where it came from in the sky.

From there, scientists create images using this data — not just for beauty, but for analysis. The colors are carefully chosen to represent different kinds of light or energy, turning raw space data into a visual story we can explore and understand.

In this Astrolympics activity series from NASA's Chandra X-ray Observatory, you'll get to train on some of the steps scientists use to turn invisible data into powerful images — and stretch your brain muscles along the way. Get ready to color the Universe, decode the data, and go for gold in astronomical understanding!

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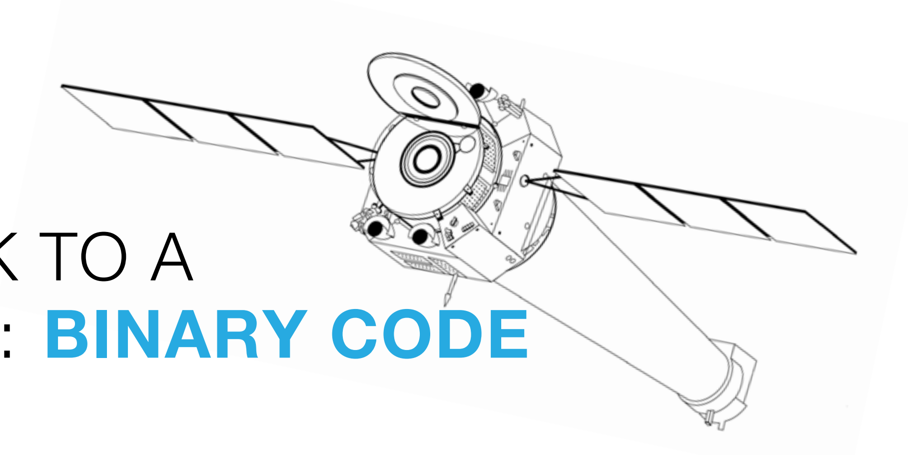


HOW TO TALK TO A SPACECRAFT: **BINARY CODE**

A STREAM OF 1'S AND 0'S

Images from NASA's Chandra X-ray Observatory—a telescope in orbit around Earth that detects X-rays—let us see the Universe in ways our eyes can't. The data first arrive at the Chandra X-ray Center in Cambridge (USA) as streams of 1s and 0s that computers translate into images. Teams of experts use specialized software to process this information so we can study and enjoy the results.

Chandra orbits Earth in a long oval path, reaching about a third of the way to the Moon. As it gathers data, it converts everything into binary (1s and 0s) and sends it across space to NASA's Deep Space Network antennas in Australia, Spain, and California. From there, the data travel to NASA's Jet Propulsion Laboratory before reaching the Chandra X-ray Center, a journey that can take a few days.

Once the data arrive, they are sorted and analyzed. Some experts study the instruments and spacecraft systems, while others transform the data into the scientific images we see.

THE GOLDSTONE DEEP SPACE COMMUNICATIONS COMPLEX, LOCATED IN THE MOJAVE DESERT IN CALIFORNIA, IS ONE OF THREE COMPLEXES THAT COMPRISE NASA'S DEEP SPACE NETWORK (DSN).

In addition to our telescopes in space, many other devices use binary code. Binary code is essentially a system that uses only two digits to represent things ("bi" means two). You can think of each 1 and 0 like an "on" and "off" position of a switch. Another similar system is Morse code, which uses short and long bursts of either sound or light. Binary code is a simple, effective way to talk to machines (computer hardware for example) because with electricity, it's either on or off.

Our cell phones, computers, and other digital equipment use a 256-letter alphabet if they are based in the English language. Twenty-six of those characters are uppercase letters (A B C D…), 26 are lowercase (a b c d…), plus Arabic numbers (1 2 3 4…), special characters (! @ # $…), as well as characters for spacing, line breaks and even simple sounds. These characters are each assigned an 8-character binary equivalent. The location of each "1" represents that position's value, which is used to calculate the total value of the binary number. The positions of all eight characters then equal a fixed number value. The letter A for example is written as "01000001". On the following page you'll see a chart of uppercase and lowercase English language alphabet characters.

In this way, binary code can be thought of as a foreign dialect that needs to be translated into a language that you can understand. Rather than different letters or characters that you might find in Russian or Chinese, binary code is "spoken" in these eight ones and zeros in different patterns. If you know the code, or how to translate, you (or a computer) can "read" or understand what the binary language is saying.

For example, here is "USA" written in binary code:

01010101 | 01010011 | 01000001

Scan to learn more:

Here is a chart of alphabet characters:

A	01000001	H	01001000	O	01001111	V	01010110
B	01000010	I	01001001	P	01010000	W	01010111
C	01000011	J	01001010	Q	01010001	X	01011000
D	01000100	K	01001011	R	01010010	Y	01011001
E	01000101	L	01001100	S	01010011	Z	01011010
F	01000110	M	01001101	T	01010100		
G	01000111	N	01001110	U	01010101		

Use the chart above to write your name in code.

Can you tell what is written here below?

01000011 | 01001000 | 01000001 | 01001110
01000100 | 01010010 | 01000001

PIXEL BATTLESHIP

How do you make images of things in space?
When a telescope captures data, they do not arrive as an assembled snapshot. Instead, the spacecraft streams data encoded in the form of ones and zeroes, which are eventually translated into various formats, including images. Satellite and spacecraft images are not really photographs, but pictorial presentations of measured data in different bands of the electromagnetic spectrum (i.e. radio, infrared, visible, ultraviolet, X-ray, gamma ray).

When a satellite observes an object in space, its camera records photons. These photons come down to Earth from the spacecraft via a network in the form of 1's and 0's. Scientific software then translates that data into an event table that contains the time, energy and position of each photon that struck the detector during the observation. The data is further processed with software to form the visual representation of the object. One colored image is then assembled from separate black and white images taken through colored filters.

This paper-based activity connects the process of making astronomical images by translating information from one form to another.

Blackhole in M87
Distribute blank 10 x 10 grids and pencils to participants.

Like Bingo, you'll call each pixel combination, letter then word. Each student will mark that square with an X.

This time, you'll be using smaller pixels and include intensity or shading to show more detail in the image. See example of the the shading key at the bottom of the grid. Areas with a 0 have little to no photons and will be very dark. Lighter areas will have more photons and will have a higher number (1, 2 or 3).

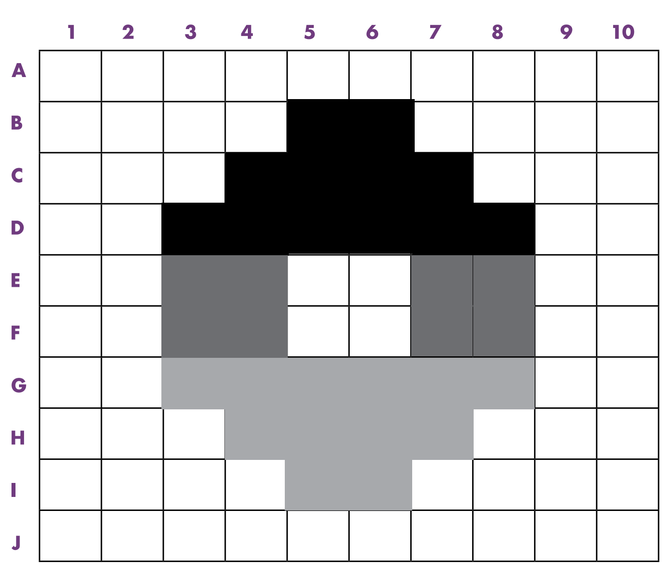
Here you will use numbers in the grid instead of X's

The combinations are as follows:
For 0 – B5, B6, C4, C5, C6, C7, D3, D4, D5, D6, D7, D8
For 1 – E3, E4, E7, E8, F3, F4, F7, F8
For 2 – F3, F4, F5, F6, F7, F8, H4, H5, H6, H7, H8, I5, I6

Give participants time to shade in their marked squares according to the Shading Values key.

Shading Values 0 1 2

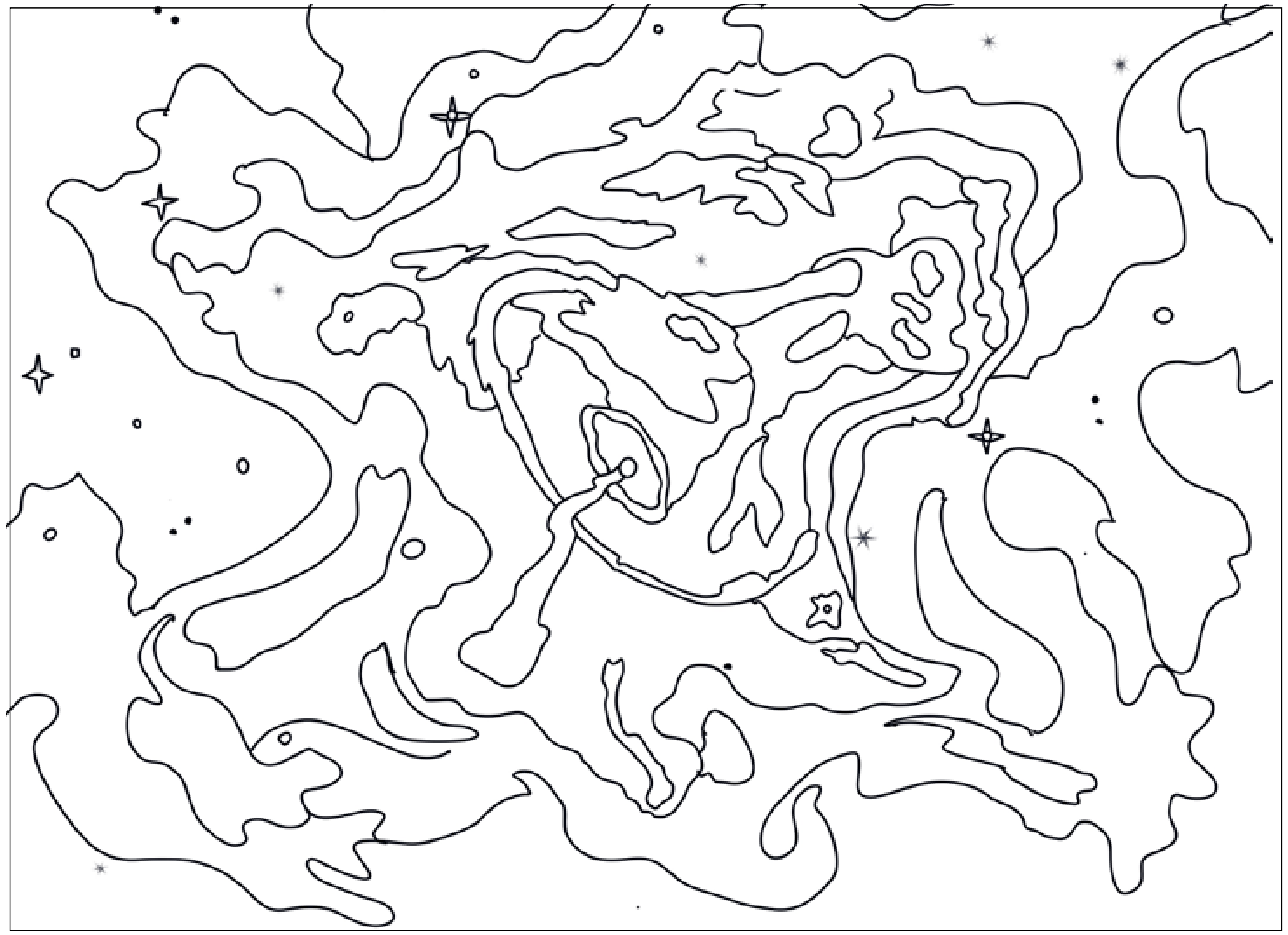
	1	2	3	4	5	6	7	8	9	10
A										
B					0	0				
C				0	0	0	0			
D			0	0	0	0	0	0		
E			1	1			1	1		
F			1	1			1	1		
G			2	2	2	2	2	2		
H				2	2	2	2			
I					2	2				
J										



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

Scan to learn more:

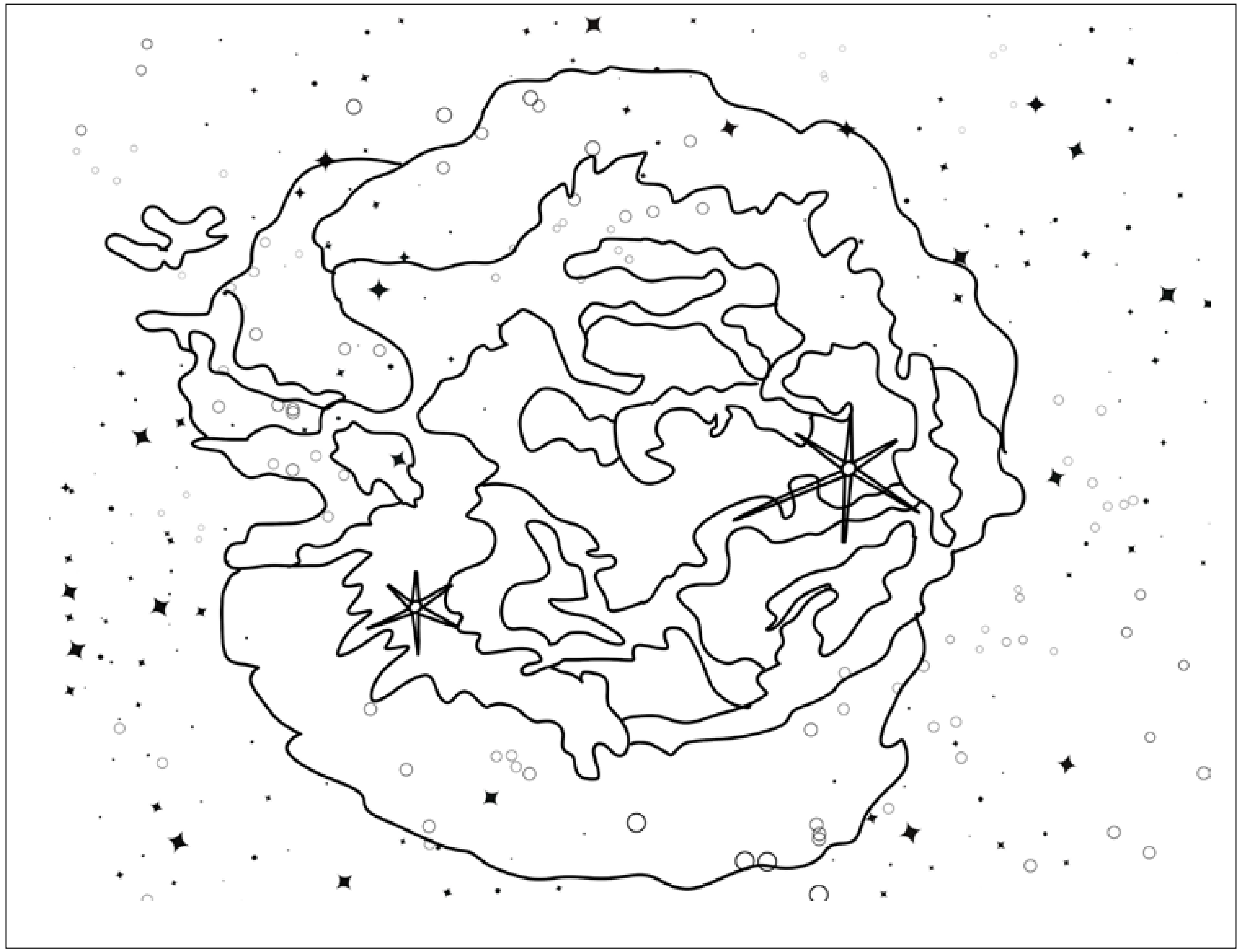
CRAB NEBULA



The Crab Nebula has been studied by people since it first appeared in Earth's sky in 1054 A.D. Modern telescopes like NASA's Chandra X-ray Observatory and NASA's James Webb Telescope have captured its enduring engine powered by a quickly spinning neutron star that formed when a massive star collapsed. The combination of rapid rotation and a strong magnetic field generates jets of matter and anti-matter flowing away from its poles, and winds outward from its equator.

Listen to Crab Nebula

SUPERNOVA CASSIOPEIA A



Cassiopeia A (Cas A) was a massive star that used up all of its fuel and exploded. The scattered, glowing remains from the explosion are called a supernova remnant. Cas A's explosion produced a cloud of very hot (50 million degree) gas that is still expanding. Chandra's sharp focus allowed scientists to identify a dot in the center that is the hot, superdense neutron star formed as a result of the star's collapse and explosion.

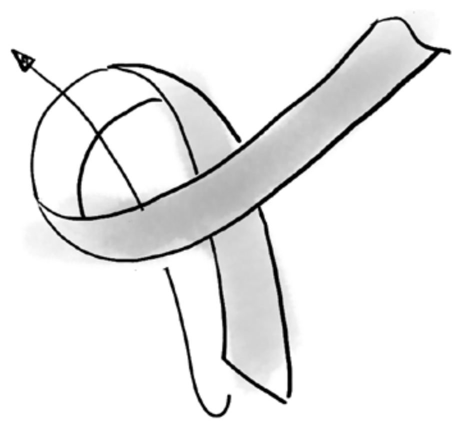
Listen to Cassiopeia

ORIGAMI UNIVERSE

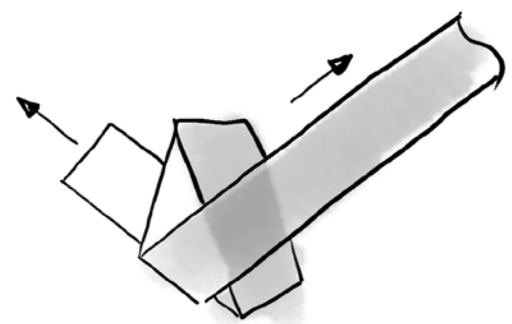
Origami is an ancient Japanese style of paper folding. It is not only a decorative art form. Origami provides solutions to many problems in modern science and engineering! For example, origami-inspired techniques are used to unfold stents in clogged arteries, release airbags during automobile collisions, and even unfurl the large mirror for the James Webb Space Telescope.

In astrophysics, there are instances where the expansion and unpacking of origami demonstrates what scientists witness. For instance, when a star about 10 to 15 times more massive than our Sun runs out of nuclear fuel, it will collapse onto itself and then create a giant explosion. This energetic event, known as a supernova, hurls the outer layers of the star into space, creating an elegant tapestry of energy and stellar debris. NASA's Chandra X-ray Observatory has looked at many of these explosions and the debris fields they leave behind (called "supernova remnants".)

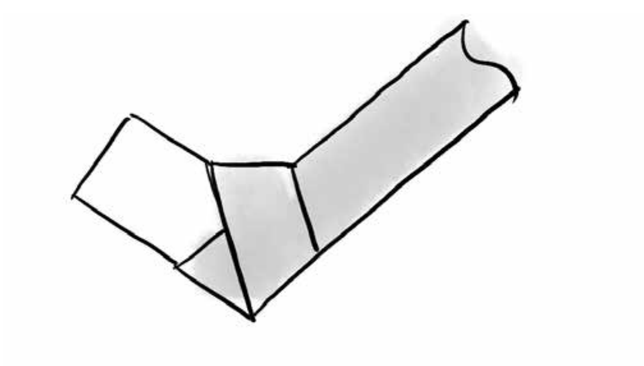
Use a long narrow strip of paper to create your star like the strip on the right.



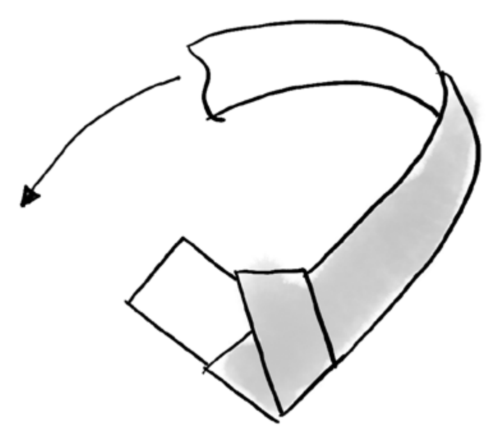
1 Make a loop at one end of the paper. Weave the short end of the paper through the loop.



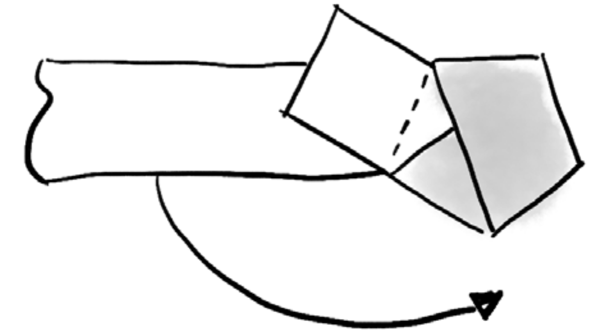
2 Tighten knot and press flat.



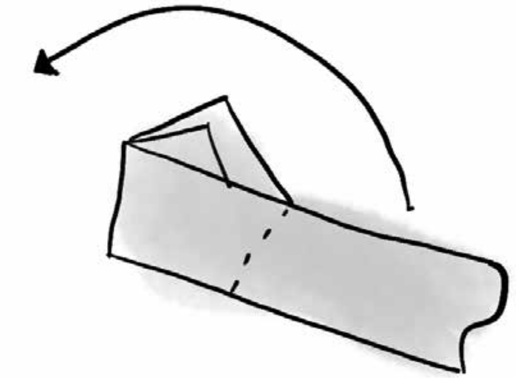
3 Fold short-end of paper down towards center of star. If it is too long, tear off a small piece.



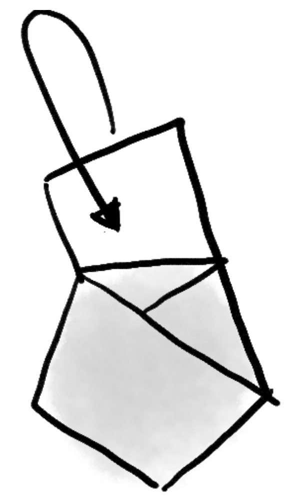
4 Fold long-end of paper up. Make sure edges line up right on top of one another.



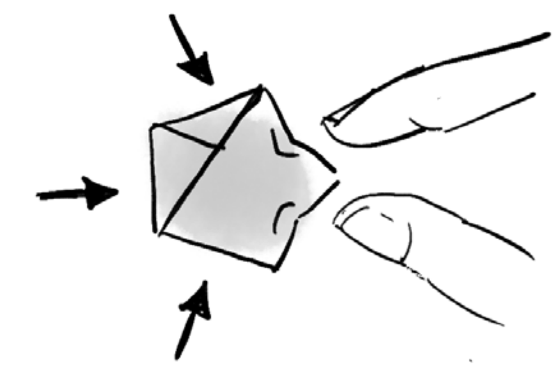
5 Flip paper around so long-end of paper is pointing down again.



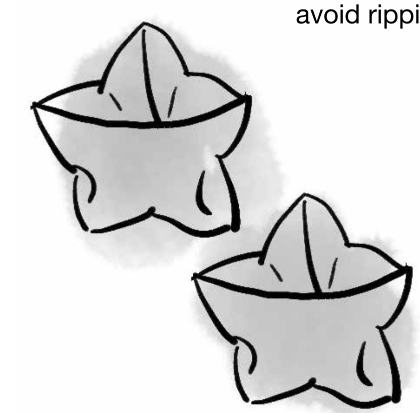
6 Fold long-end of paper up and to the left. Make sure edges line up one on top of the other.



7 Flip paper around again so long-end of paper is pointing down.



8 Pinch the sides and puff out your star! Be careful here, too, to avoid ripping your star.



Scan watch a how-to video:

Use this strip of paper to create your star. Cut along the edge to begin!

LIGHT UP BLACK HOLES

A black hole is a dense, compact object whose gravitational pull is so strong that - within a certain distance of it - nothing can escape, not even light.   These bizarre objects are found across the Universe -- within double star systems and at the centers of galaxies where giant black holes grow. X-ray telescopes like NASA's Chandra X-ray Observatory can see superheated matter that is swirling toward the event horizon of a black hole, and help reveal how black holes impact their environments, how they behave, and their role in helping shape the evolution of the cosmos.

In 2019, the Event Horizon Telescope (EHT), a network of radio antennae around the globe, captured the first image of a black hole's shadow. The black hole is located in the galaxy Messier 87, or M87, which is about 60 million light years from Earth. Many other telescopes have studied the M87 system and will continue to investigate the intriguing mysteries of black holes.

What is a Paper Circuit?
Paper circuits help learners of all ages explore the basics of electricity (energy that results from the existence of charged particles like electrons or protons) and conductivity (the degree to which a material can conduct electricity). Paper circuits function as simple low-voltage electronic circuits (a path through which electrons from a voltage or current source flow) made using paper, LED lights, a type of conductive tape such as copper, as well as a small battery for the power source.

Directions: Download the attached .pdf and print double-sided (so the shapes are lined up) and cut in half (you will get two handouts per page)

1. Have participants cut out the rectangle - see handout for instructions
2. Ask participants to fold paper in half on the dashed line so that the directions are on the INSIDE/images are on the OUTSIDE.
3. Punch a hole for the LED light - see template
4. Following the remaining steps outlined on the handout - placing copper tape, finding the positive lead on the LED and affixing the leads to the circuit, and folding over with the coin battery.
5. Use a binder clip to hold battery in place on the circuit (so the light stays on)

Troubleshooting

- Flip the battery over. If the LED was put in backwards, it just means the positive and negative parts of the circuit are reversed
- Check all connections - around the LED leads, alignment with the battery, any broken places in the copper tape. Use more tape to reinforce connection.

Cost: About $0.50 (50 cents) per item, estimates are provided in the materials list

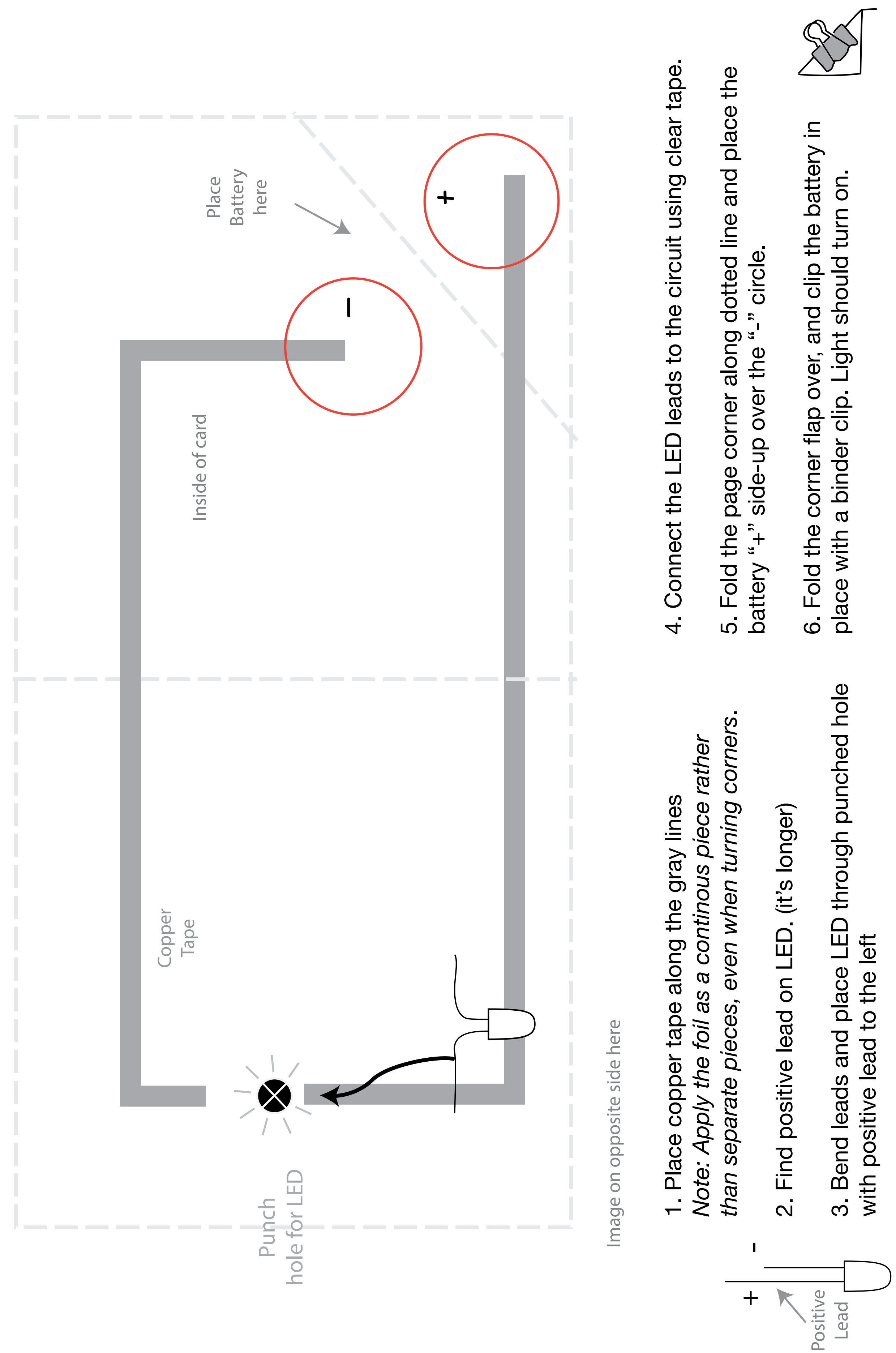
Age: approximately ages 9 & up (not for very young children/battery is a choking hazard)

Time: about 5 minutes to make a single item

Materials:

- Coin Batteries ($0.30 each)
- Copper tape with conductive adhesive ($0.10) - Less than 12 inches per badge
- LED's ($0.05)
- Small binder clips ($0.05)
- NASA Images of exploding stars/pulsars/ neutron stars (download template here: chandra.si.edu/make/template.pdf)
- Hand held hole punchers
- Small trash can – little bits of trash are produced during the activity

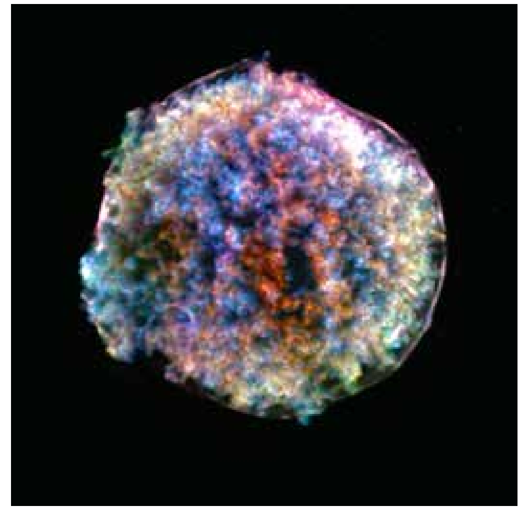
Scan watch a how-to video:



MAKE YOUR OWN SNOWFLAKE CHAIN USING REAL 3D INFORMATION!

Some of very biggest stars end their lives in dramatic explosions called “supernovas.” These supernova explosions leave behind glowing debris fields known as supernova remnants. Every supernova remnant is unique. Like snowflakes, they seem similar at first glance, but are exquisitely varied as we explore them in detail.

The curve in this project comes from real 3D data from a star that exploded, called Tycho’s Supernova Remnant. NASA’s Chandra X-ray Observatory collects the high-energy light from the blast and helps scientists build a 3D map of what it looks like. An artist then cut a slice from that model, flattened it into a drawing, and simplified the shapes so you can cut them out of paper. Put the pieces together, and you’ll build your own mini 3D version of a real exploded star!



Cost: About $0.50 (50 cents) per item

Time: 20-30 minutes to complete.

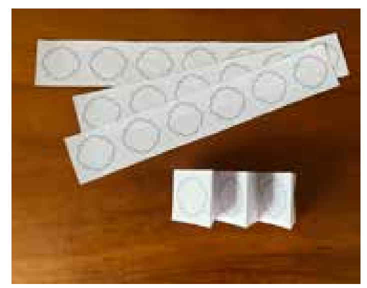
Ages: 11+

Materials:
- paper
- a black and white printer
- scissors
- tape or glue

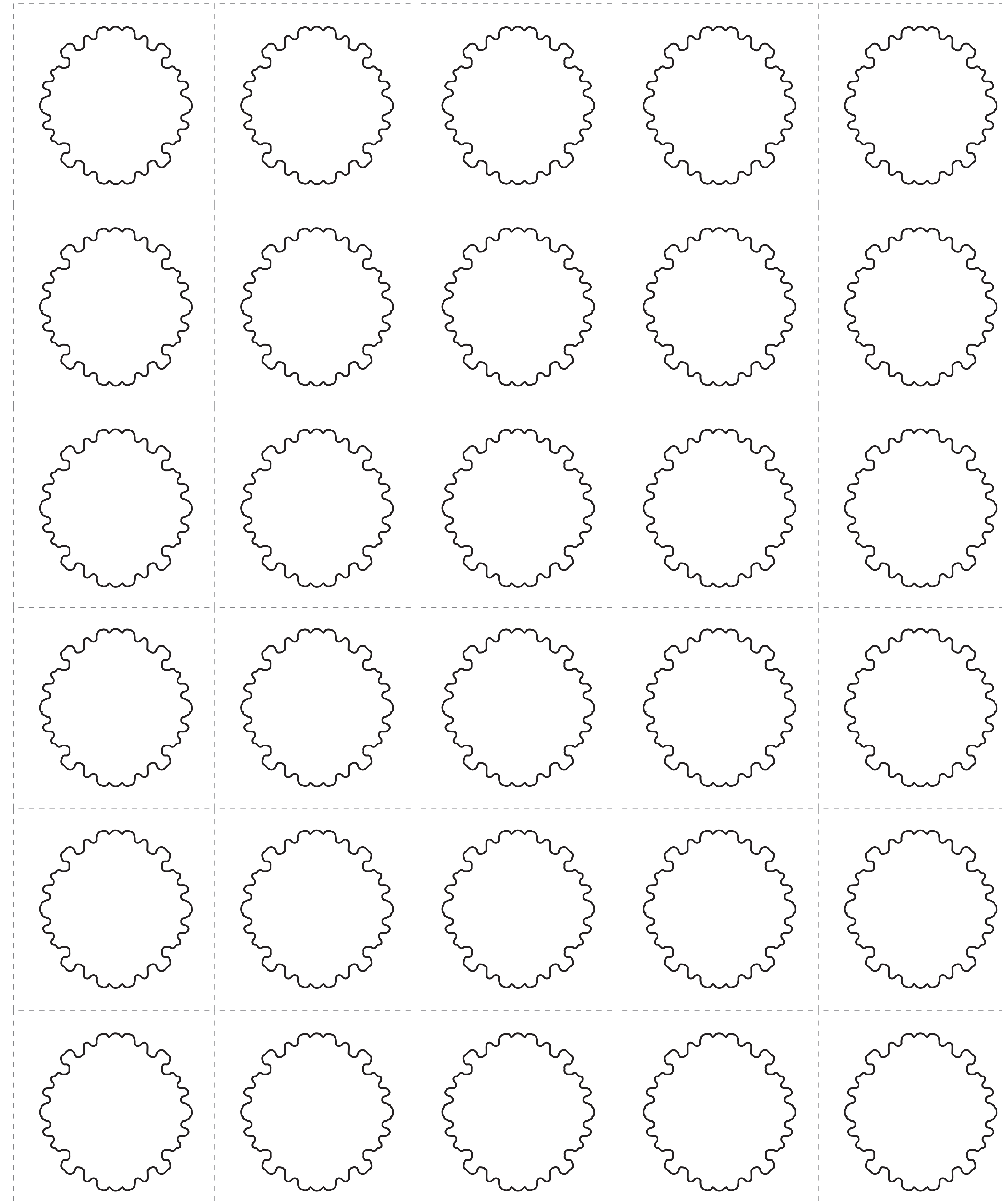
Directions: Print the first page with the strip showing the outline of one supernova at the end.

1. Fold into sixths, using the dotted lines as a guide, accordion-style, so that the outline of the supernova shows on the outside.
2. Cut through the 6 layers of paper, along both solid lines making a curvy outline of a supernova with a connecting strip through the center, your connected chain.
3. Print the other 2 pages, each showing a grid of 6 x 5 supernova outlines.
4. Cut out all 60 supernova outlines from p. 2 & p. 3. This goes fastest if you cut into strips and accordion fold each strip, cutting out 6 at a time.
5. Fold each separate supernova circle in half.
6. Using glue or scotch tape, affix 5 of the folded circles together to look like the pages of a book laying open on a desk.
7. Using one of the circles in your connected chain as the “book cover” affix a 5-piece folded structure to it.
8. Repeat steps 5-6 for each circle in your connected chain.
9. Flip the chain over and repeat steps 5-6 for the back side of the chain.

Scan watch a how-to video:

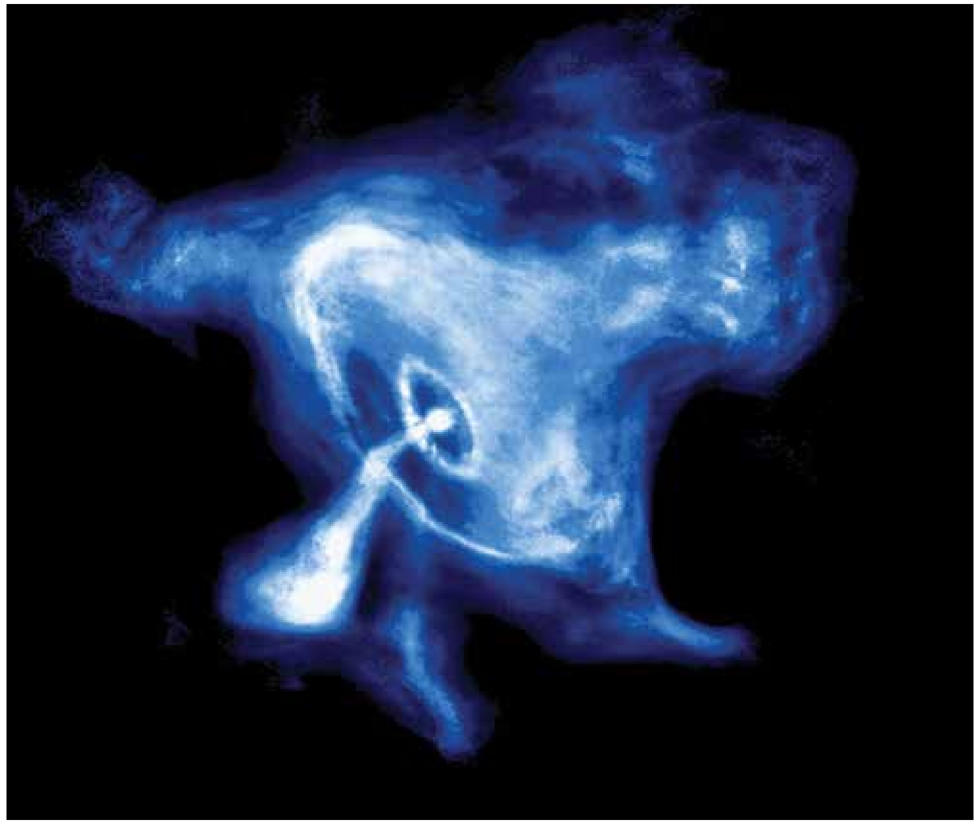


TYCHO'S SUPERNOVA REMNANT TEMPLATE



SPACE MATH

THE CRAB NEBULA: EXPLORING A PULSAR UP CLOSE!



The Crab Nebula is all that remains of a massive star that exploded as a supernova, and was seen by humans for the first time in 1054 AD. Located 6000 light years away, it is still being powered by a rapidly-spinning neutron star. The electromagnetic energy from this spinning, magnetized object (also called a pulsar) produces the amazing high-energy cloud of particles now seen clearly by the NASA, Chandra Observatory in the image to the left.

This image gives the first clear view of the faint boundary of the Crab Nebula's X-ray-emitting pulsar wind nebula. The combination of rapid rotating and strong magnetic field generates an intense electromagnetic field that creates jets of matter and anti-matter moving away from the north and south poles of the pulsar, and an intense wind flowing out in the equatorial direction. The inner X-ray ring is thought to be a shock wave that marks the boundary between the surrounding nebula and the flow of matter from the pulsar. Energetic electrons and positrons (a form of antimatter) move outward from this ring to produce an X-ray glow that Chandra sees as a ghostly cloud in the image above.

PROBLEM 1

The width of this image is about 5 light years. If the elliptical ring near the center is actually a circular ring seen at a tilted angle, what is the radius of this in:

A) light years?

B) kilometers?

(Note: 1 light year = 5.9 trillion kilometers).

PROBLEM 2

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

PROBLEM 3

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

ANSWER KEY 60

Problem 1 answer

the scale of this image can be found using a millimeter ruler. When printed, the image is about 70 mm. The scale is then 5 ly/70mm = 0.071 ly/mm. The radius of the ring will be the maximum radius of the elliptical ring, which you can see by drawing a circle on a piece of paper and tilting it so it looks like an ellipse. On the image, the length of the major axis of the ellipse is 10 mm, so the radius of the circle is 5 mm.

A) Using the scale of the image we get 5 mm x 0.071 ly/mm = 0.36 light years.

B) The radius in kilometers is just 0.36 ly x 5.9 trillion km/1 ly = 2.1 trillion km.

Problem 2 answer

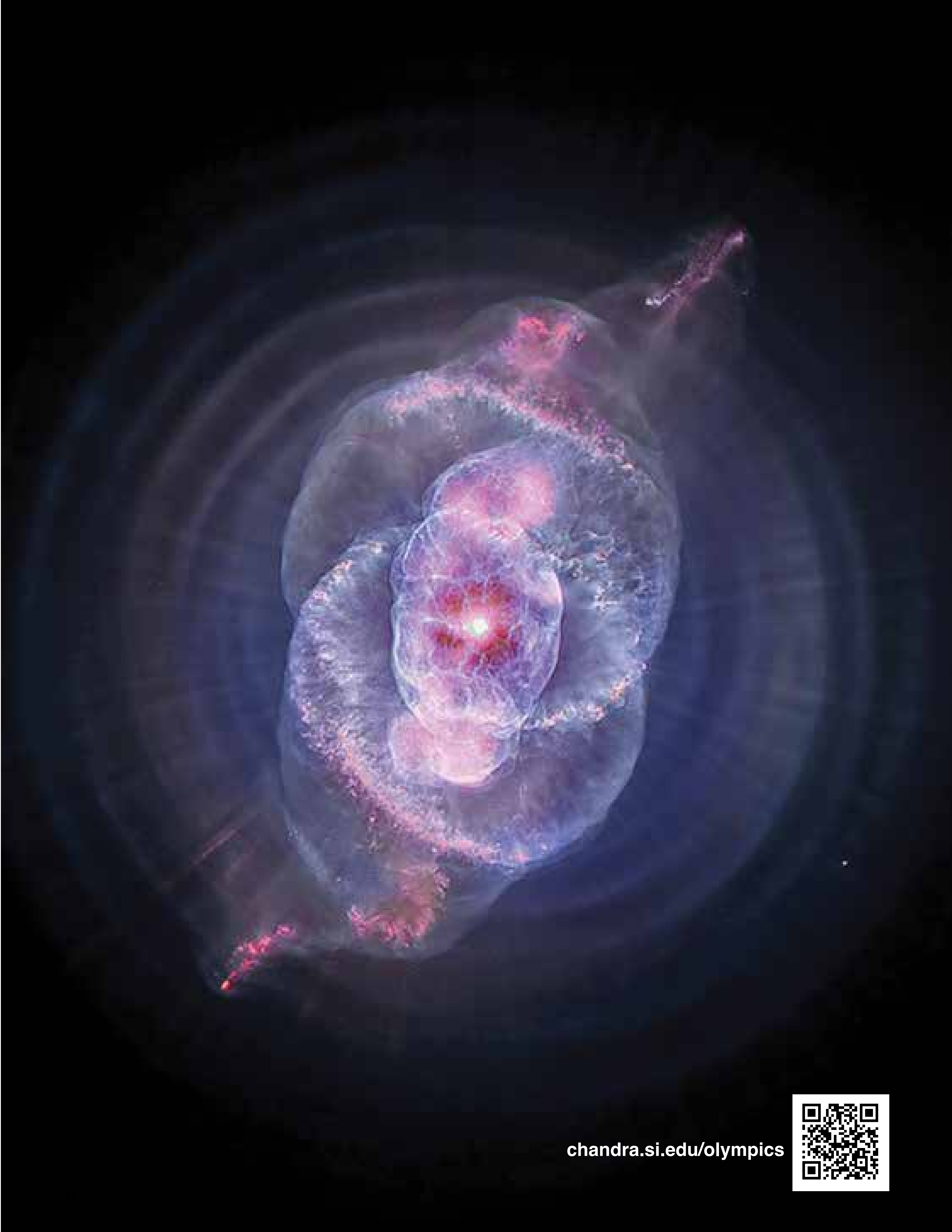
Time = distance/speed, so for
s = 0.95x300,000 km/s = 285,000 km/s, and
d= 2.1 trillion km, we get T = 2,100,000,000,000 / 285,000 = 7,368,421 seconds.

Converting to days: 7,368,421 seconds x (1 hour/3600 sec) x (1 day/24 hours) = 85.28 days. To the nearest day, this is 85 days.

Problem 3 answer

They would have to wait 85 days after seeing the burst of light because light travels faster than the matter in the particles.

Note: Another way to appreciate how much faster light travels, calculate the number of days it would take for the pulse of light to reach the ring, compared to the 85 days taken by the particles. The light pulse would take 2.1 trillion km/300,000 km/s = 7 million seconds or about 81 days. So astronomers would have to wait 81 days to see whether the light pulse affects the ring, and then another 4 days for the particles to arrive.



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