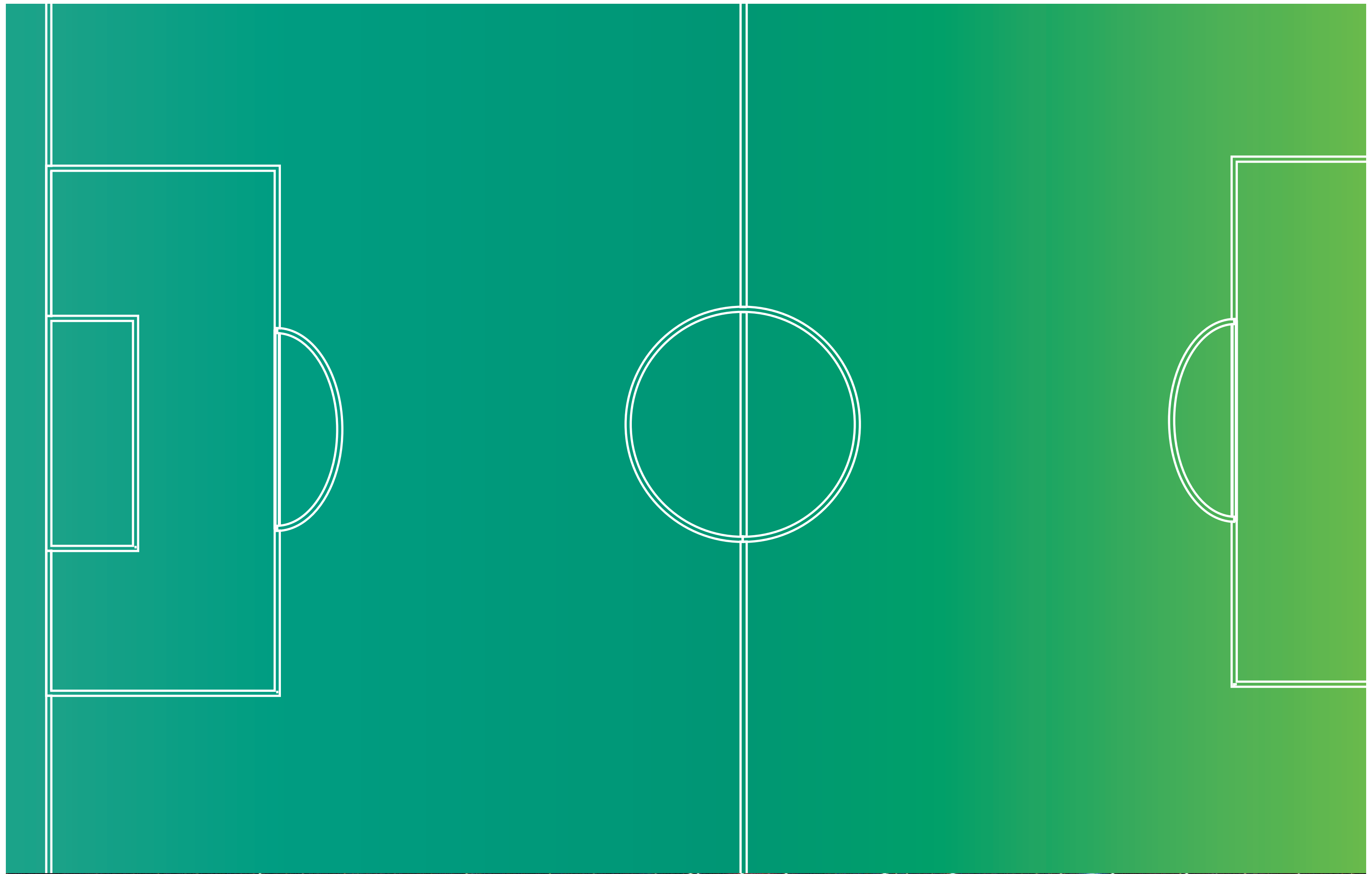
COSMIC PITCH

Training to See the Universe Through the World's Game

Photo by Laura Rincón



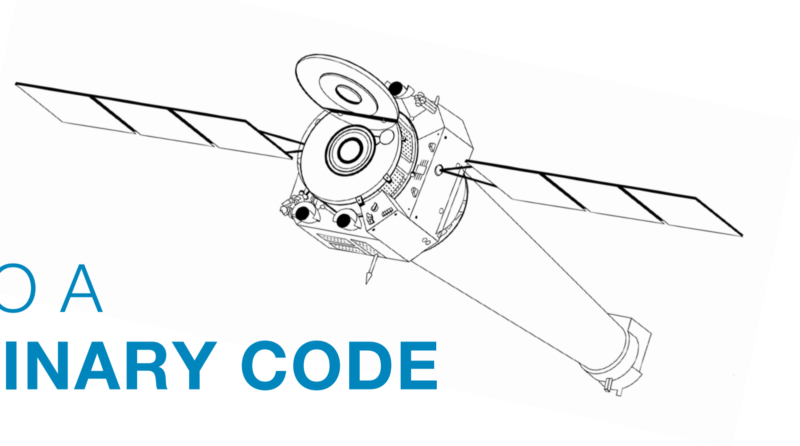
Like elite soccer players who train for speed, control, and precision, scientists train to understand forces that shape our universe. Whether it's a perfectly curved free kick or a jet of energy blasting from a black hole, the same laws of physics are always in play.

One main challenge in both soccer and space science is understanding what we can't directly see. On the field, players rely on data, angles, timing, and experience to predict where the ball will go next. In space, scientists rely on telescopes to detect invisible forms of light — not just the visible light human eyes can see, but also radio, infrared, ultraviolet, X-ray, and gamma-ray light. Each type of light reveals something different about the cosmos, like different stats revealing the story of a match.

When space telescopes like NASA's James Webb Space Telescope, Chandra X-ray Observatory, or Hubble Space Telescope, collect this light, they send the data back to Earth using a global network of antennas. The information arrives as binary code — strings of 1s and 0s — similar to the digital data used to track speed, distance, and performance in modern sports. Scientists decode this data to learn when light arrived, how energetic it was, and where it came from in the sky.

From there, scientists turn data into images — not just to make something beautiful, but to analyze motion, energy, and structure. Colors are carefully chosen to represent different types of light or energy, transforming invisible data into visuals we can explore and understand.

In this Cosmic Pitch activity series from NASA's Universe of Learning and Chandra X-ray Observatory, you'll decode data, track motion, and visualize energy — training your brain the same way athletes train their bodies. Get ready to see the universe through the lens of the world's favorite game.



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).

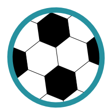
In addition to our telescopes in space, many other devices use binary code. Binary code is essentially a system that uses only two digits to represent things ("bi" means two). You can think of each 1 and 0 like an "on" and "off" position of a switch. Another similar system is Morse code, which uses short 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 "Soccer" written in binary code:

01010011 | 01001111 | 01000011 | 01000011 | 01000101| 01010010



A soccer ball can travel at over **100 mph (160 kph)** when it is first kicked by a player's foot!

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

SCAN TO LEARN MORE!

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.

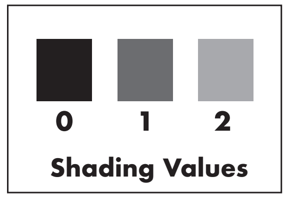
Like Bingo, you'll call each pixel combination, letter then word. Each student will mark that square with an X.

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).

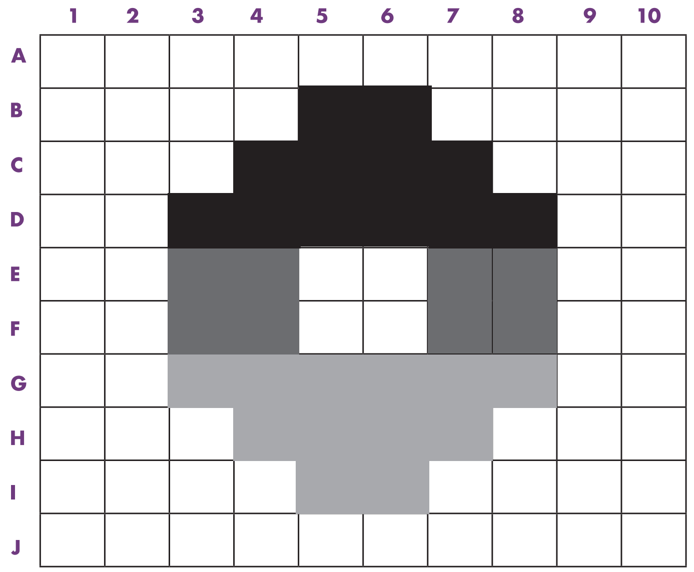
Here you will use numbers in the grid instead of X's

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

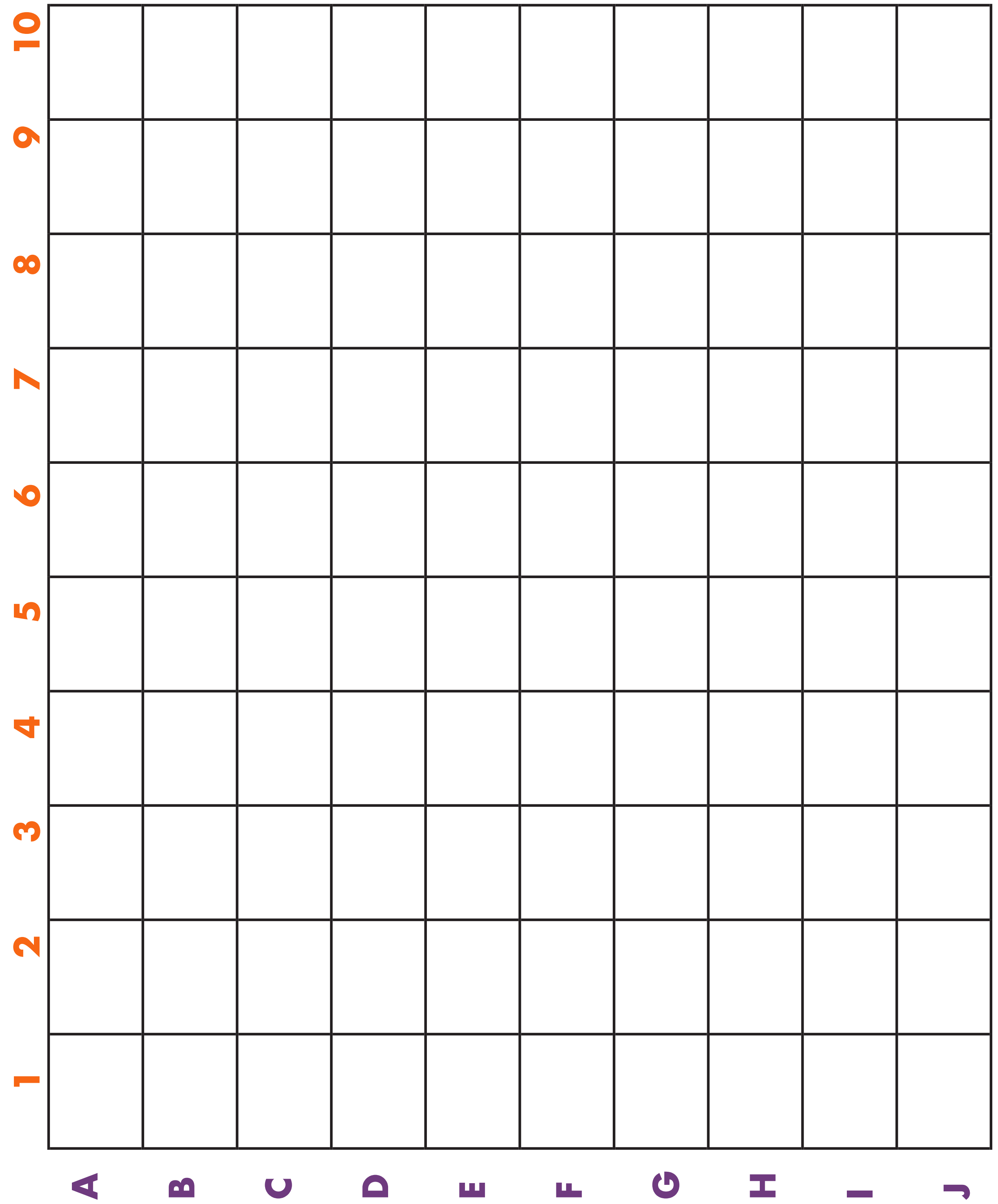
Give participants time to shade in their marked squares according to the Shading Values key.

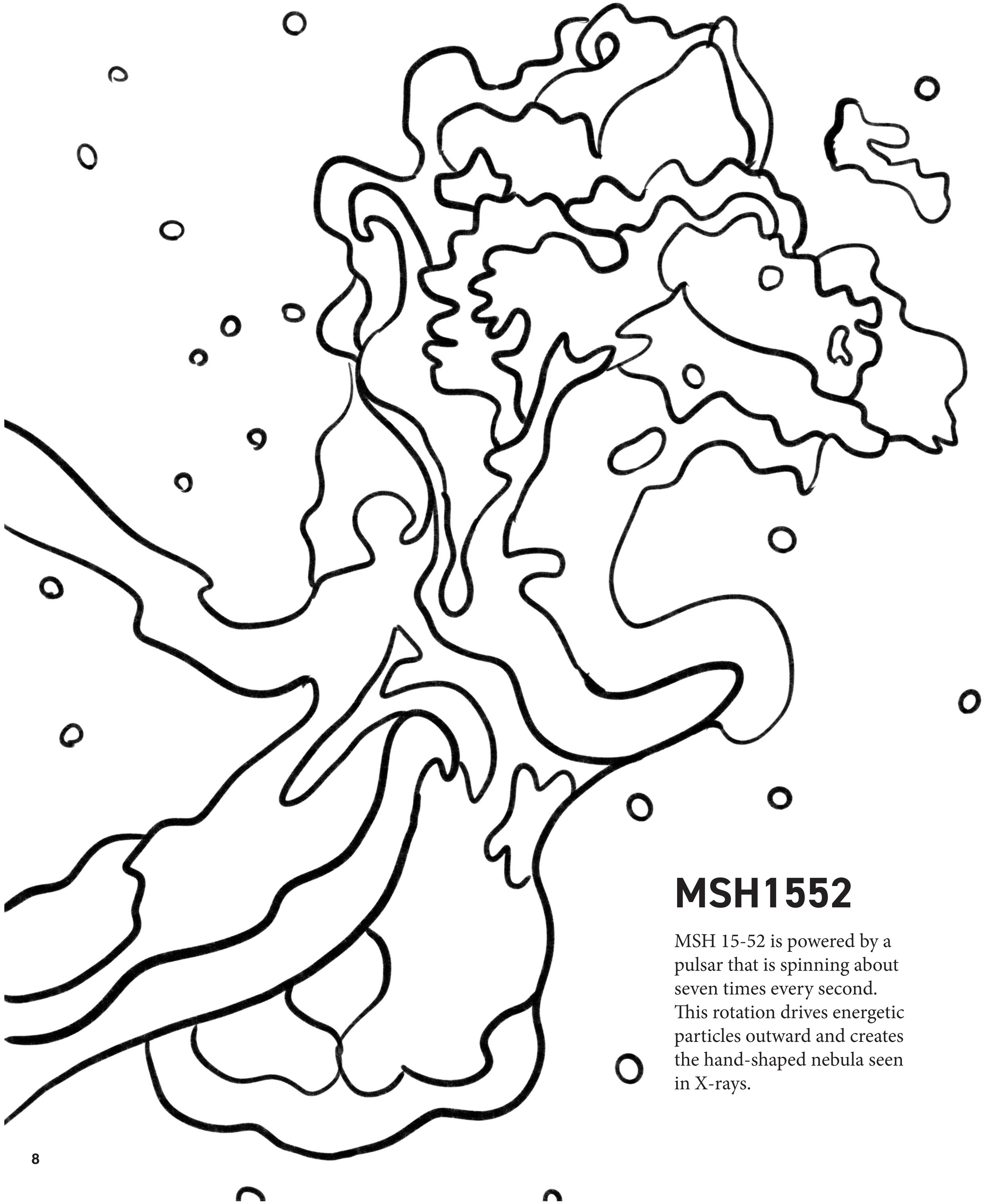


	1	2	3	4	5	6	7	8	9	10
A										
B					0	0				
C				0	0	0	0			
D			0	0	0	0	0	0		
E			1	1			1	1		
F			1	1			1	1		
G			2	2	2	2	2	2		
H				2	2	2	2			
I					2	2				
J										



SCAN TO LEARN MORE!



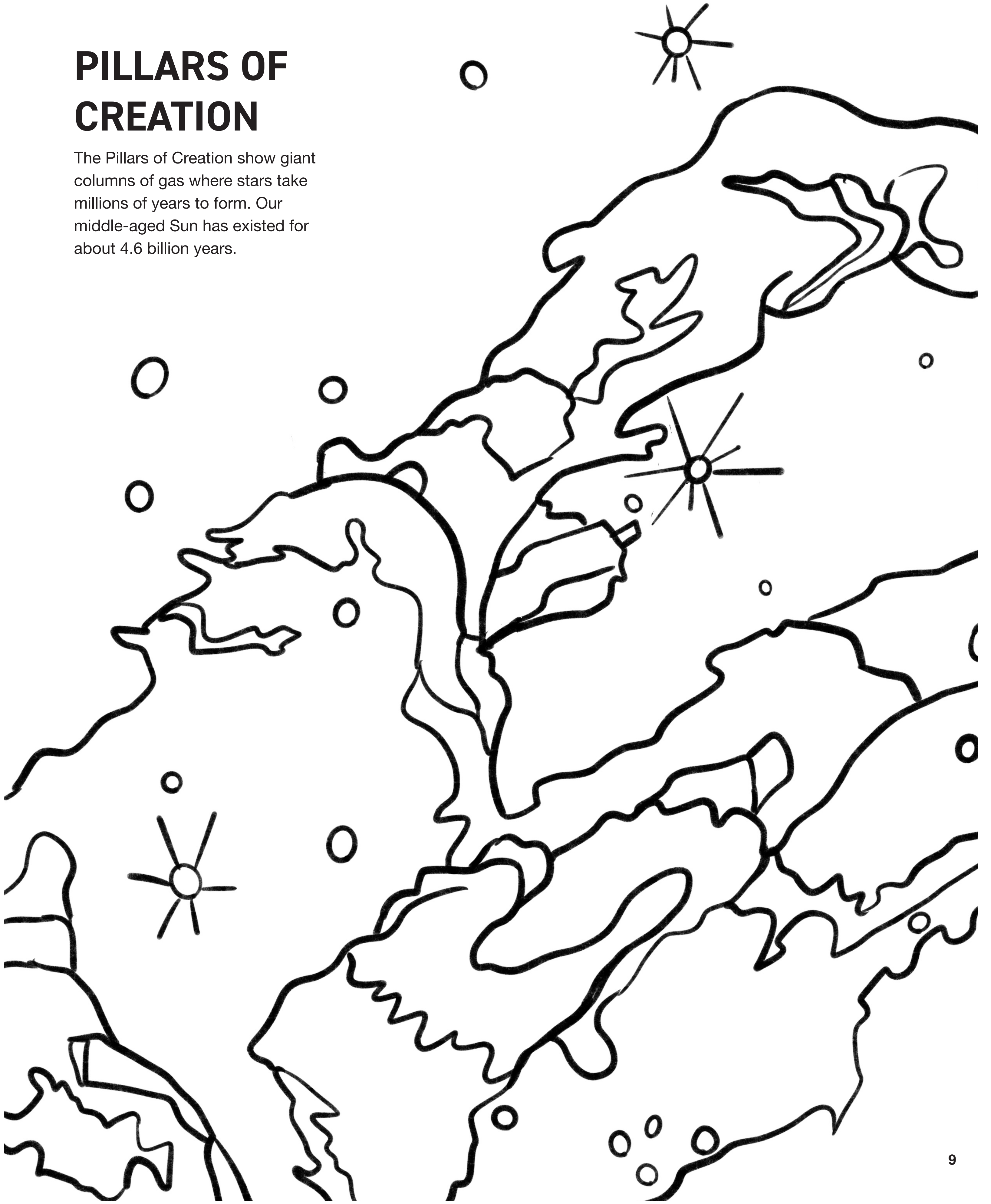


MSH1552

MSH 15-52 is powered by a pulsar that is spinning about seven times every second. This rotation drives energetic particles outward and creates the hand-shaped nebula seen in X-rays.

PILLARS OF CREATION

The Pillars of Creation show giant columns of gas where stars take millions of years to form. Our middle-aged Sun has existed for about 4.6 billion years.

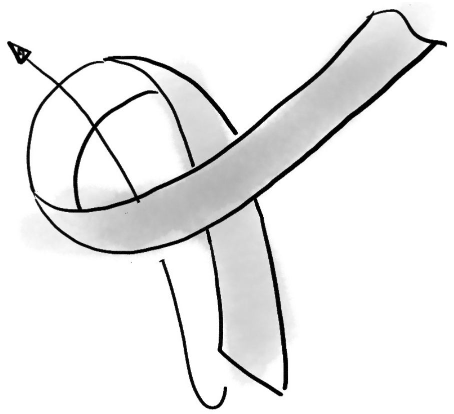


Origami Universe

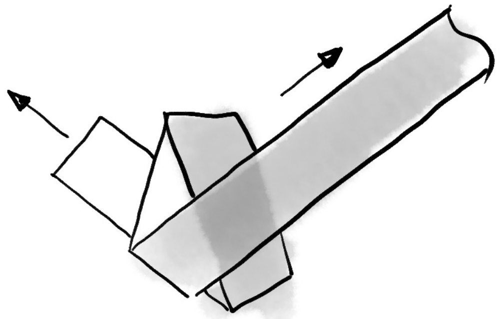
Origami is an ancient Japanese style of paper folding. It is not only a decorative art form. Origami provides solutions to many problems in modern science and engineering! For example, origami-inspired techniques are used to unfold stents in clogged arteries, release airbags during automobile collisions, 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".)

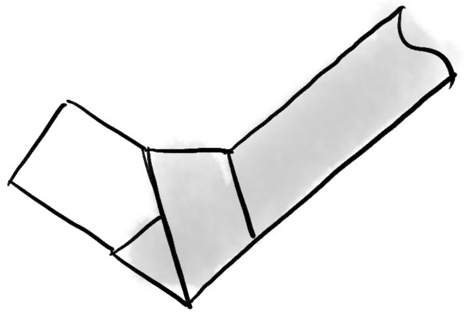
Use a long narrow strip of paper to create your star like the strip on the right.



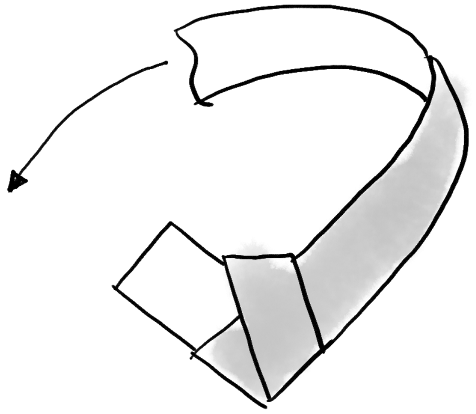
1 Make a loop at one end of the paper. Weave the short end of the paper through the loop.



2 Tighten knot and press flat.

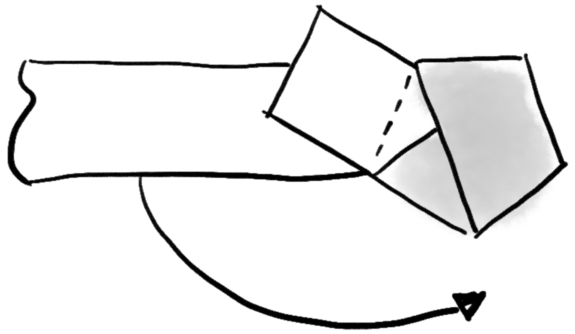


3 Fold short-end of paper down towards center of star. If it is too long, tear off a small piece.

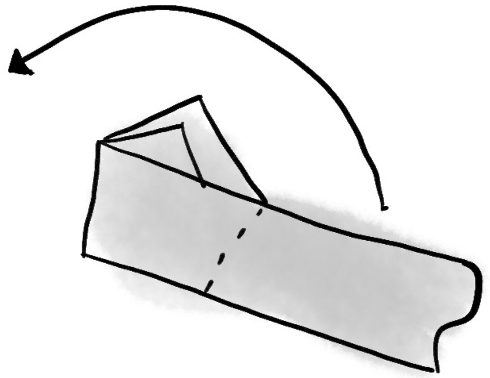


4 Fold long-end of paper up. Make sure edges line up right on top of one another.

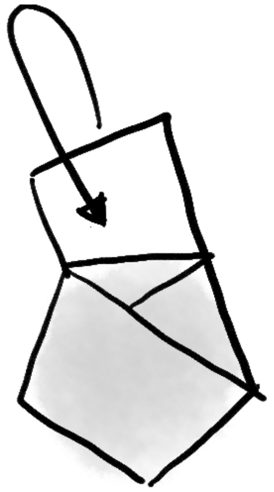
Scan watch a how-to video:



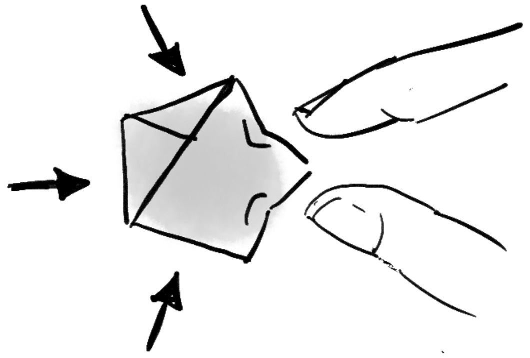
5 Flip paper around so long-end of paper is pointing down again.



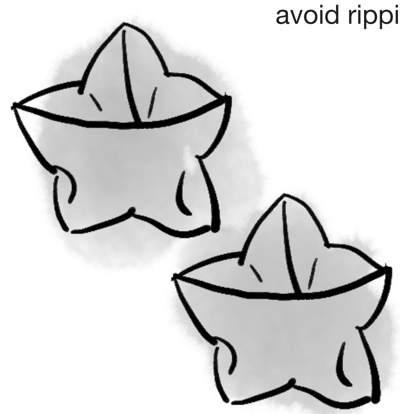
6 Fold long-end of paper up and to the left. Make sure edges line up one on top of the other.



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.



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.

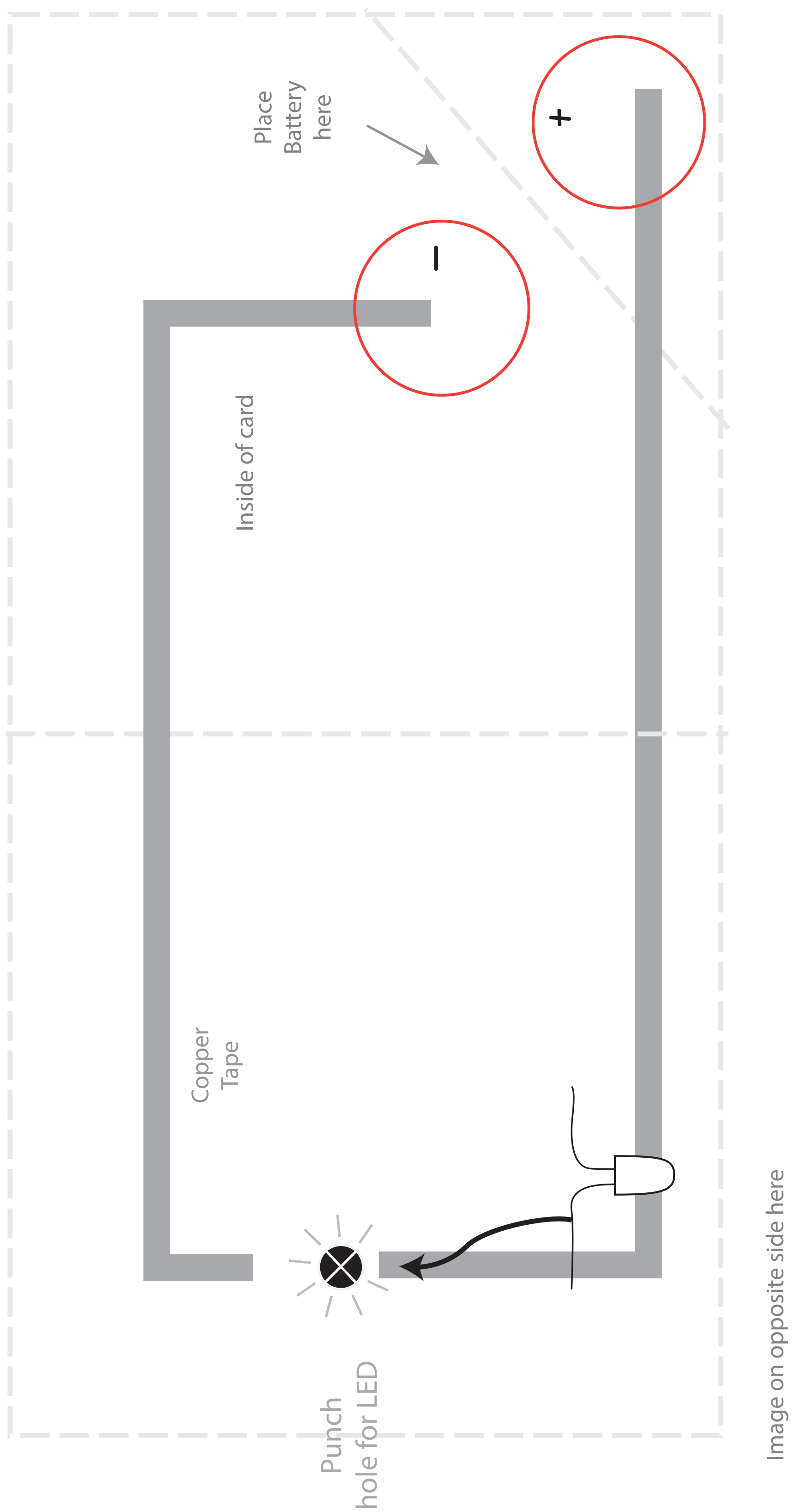
Cost: About $0.50 (50 cents) per item, estimates are provided in the materials list

Time: about 5 minutes to make a single item

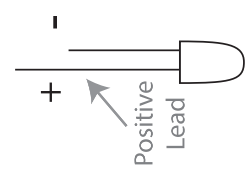
Ages: 6-10

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

Scan watch a how-to video:



1. Place copper tape along the gray lines *Note: Apply the foil as a continous piece rather than separate pieces, even when turning corners.*
2. Find positive lead on LED. (it's longer)
3. Bend leads and place LED through punched hole with positive lead to the left



4. Connect the LED leads to the circuit using clear tape.
5. Fold the page corner along dotted line and place the battery "+" side-up over the "-" circle.
6. Fold the corner flap over, and clip the battery in place with a binder clip. Light should turn on.

Make your own supernova 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.

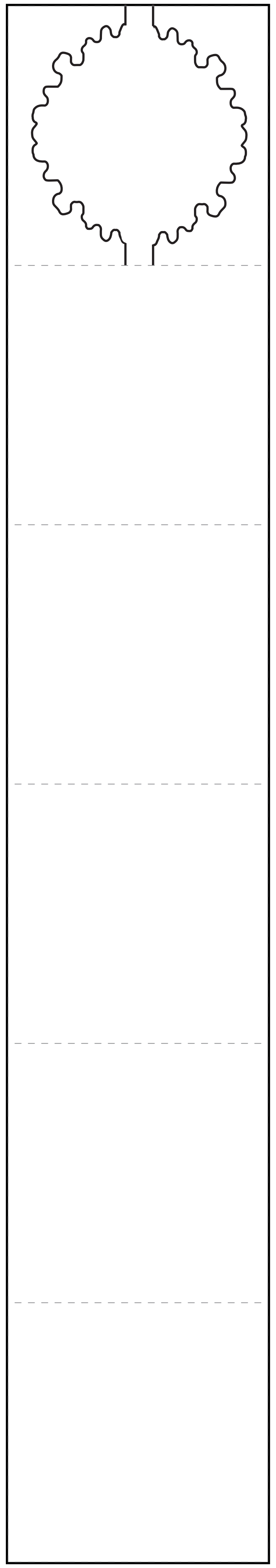
Ages: 11+

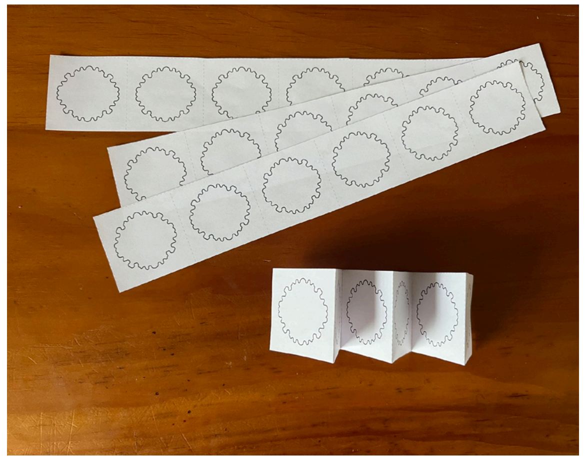
Materials:
- paper
- a black and white printer
- scissors
- tape or glue

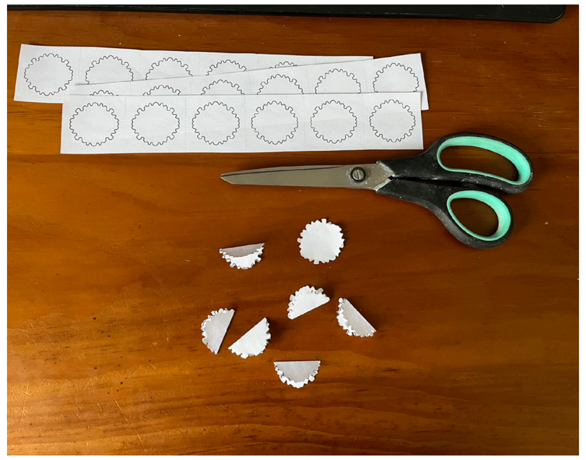
Directions:

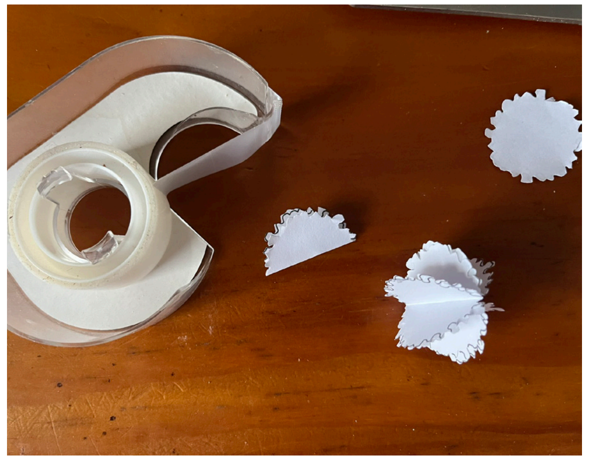
Print the first page with the strip showing the outline of one supernova at the end.

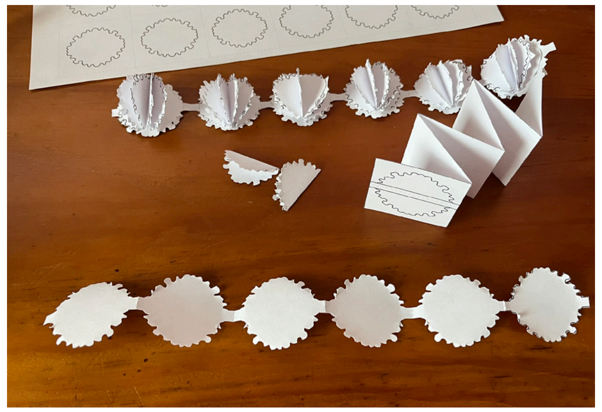
1. Fold into sixths, using the dotted lines as a guide, accordion-style, so that the outline of the supernova shows on the outside.
2. Cut through the 6 layers of paper, along both solid lines making a curvy outline of a supernova with a connecting strip through the center, your connected chain.
3. Print 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.



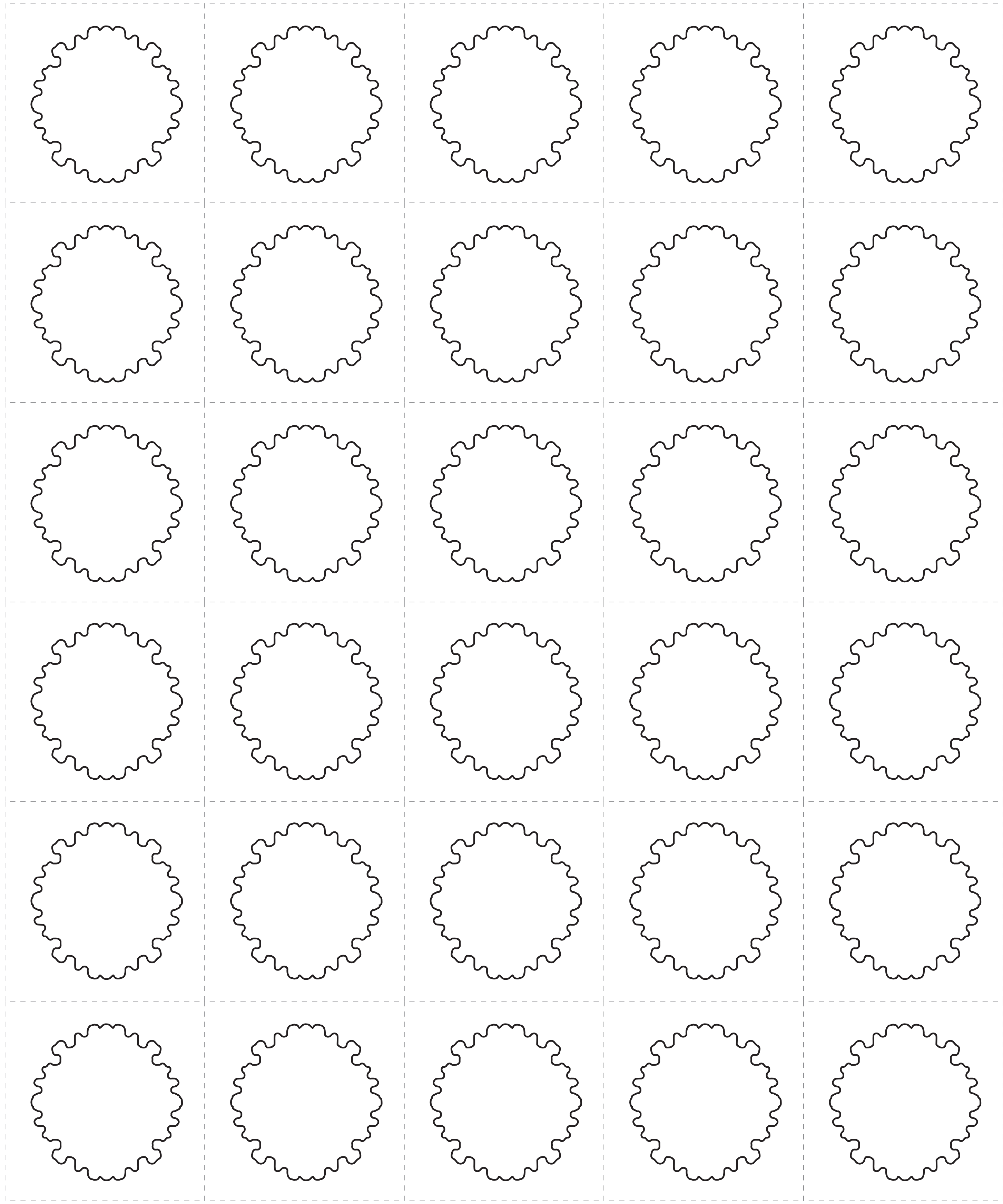








TYCHO'S SUPERNOVA REMNANT TEMPLATE



12 Years, 10 Asteroids, 1 Spacecraft

12 años, 10 asteroides, 1 nave espacial

The Lucy spacecraft is going on a long and exciting journey. She will travel for 12 years and fly incredibly close to 8 asteroids. That's more asteroids at once than any other space mission!

La nave espacial Lucy irá en un largo y emocionante viaje. Lucy viajará por 12 años y sobrevolará 8 asteroides. ¡Esos son más asteroides a la vez que cualquier otra misión espacial!

Solar Seek & Find

Circle the words below.

Astronomical unit
Aurora
Corona
Eight minutes
Energy
Flare
Fusion
Heat
Hydrogen
Light
Main sequence
Solar system
Solar wind
Star
Sunspot

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

Fill in the Black (blank) Holes!

WORD BANK
black hole
star
event horizon
radio
x-rays
quasar
supermassive
stellar mass
supernova
gravity
jet
light
mass
volume

The Birth of a Monster

A black hole is born when a very massive (1) ______________________ runs out of fuel and collapses. If the star is big enough, it will explode in a powerful blast called a (2) ______________________. What remains is crushed into a tiny space. Because all that (3) ______________________ is packed into such a small (4) ______________________, the object has an incredibly high (5) ______________________.

The Pull of the Void

This extreme concentration of matter creates a powerful force of (6) ______________________. It is so strong that nothing, not even (7) ______________________, can escape once it gets too close. The "point of no return" around a (8) ______________________ is known as the (9) ______________________.

Sizes and Shapes

Black holes come in different sizes. Those that are between a few to 100s of times the mass of our Sun are called (10) ______________________ black holes. However, at the center of almost every large galaxy, there is a (11) ______________________ black hole, which can be hundreds of thousands to billions of times as massive as our Sun.

Answer Key: Star | 2. Supernova | 3. Mass | 4. Volume | 5. Density | 6. Gravity | 7. Light | 8. Black hole | 9. Event horizon | 10. Stellar mass | 11. Supermassive

NASA'S UNIVERSE OF LEARNING

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Chandra X-ray Observatory
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