Science a-z

INVESTIGATION PACK TEACHER'S GUIDE

INTRODUCTION

Welcome to Investigation Packs! Your students are about to embark on an exciting new science adventure. They will dig deeper into science content, apply scientific practices, and develop skills in the language arts.

The Investigation Files, also called *I.Files*, are used by students and feature high-interest, in-depth science content. In each investigation, students will

- answer text-dependent questions based on evidence
- perform close reading and then write in response to reading
- participate in scientific argument with peers and seek common answers
- practice *21st Century Skills* including communication, collaboration, critical thinking, and creativity
- have fun learning!

ACTIVITY OVERVIEW

1. Each student in a group reads at least one different *I.File* and collects evidence on his or her *I.File Response Sheet*.
2. Groups discuss what their *I.Files* had in common in order to answer the Key Question.
3. The whole class comes to a consensus on the answer to the Key Question.
4. Students read a *Mystery File* and discuss in groups whether it fits with the other files they read, and why or why not.

ABOUT THE RESOURCE

Each Investigation Pack includes everything you need for this activity. The investigation begins with the **Key Question**—the guiding question that students will address during their reading. It challenges students to identify what all the *I.Files* have in common. They will use evidence from various texts, as well as from their discussions, to answer the Key Question.

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Each Investigation Pack includes the following:

- The primary reading resources are *I.Files*. They each contain informational text covering a specific high-interest topic related to a Science A–Z unit. Students will interpret photographs, illustrations, maps, and graphs. **Certain embedded details are common to all the files and are integral to answering the Key Question.**

I.File
Reading Levels

Printing: The *I.Files* are intended to be printed double-sided and in color, but this is not essential. They may be printed single-sided, in black and white, or even projected or viewed on screen as needed.

TIP Laminate the *I.Files* and *Mystery File* to allow multiple uses.

Leveling: To help differentiate instruction within groups, one of the *I.Files* is written at a lower reading level, two or more are at a middle level, and one is at a higher level. These levels are represented by small dots to indicate a lower (•), middle (••), or higher (•••) reading level. Assign the appropriate file to each student within a group, or pair an emerging reader with a capable reader and ask them to read the same file.

- The *I.File Response Sheet* asks the Key Question and provides space for prior knowledge. While reading, students will record key vocabulary and evidence from the text they read. Then they will compare notes with their teammates to write their answer to the Key Question on this sheet.
- The *Mystery File* may or may not share *all* of the key details of the *I.Files*. Each *Mystery File* includes a Mystery File Question to help students decide whether the subject does or does not belong grouped with the *I.Files*. The response sheet on the back helps students make their decision using evidence from the text.
- The *I.Files Teaching Tips* are specific to the topics in the pack. They include answers to the Key Question and the *Mystery File*, common misconceptions, key vocabulary terms, solutions to Math Moments, and extensions and variations related to the files.

Contents of Each Investigation Pack

☐ 4–6 *I.Files*
☐ 1 *Mystery File*
☐ *I.File Response Sheet*
☐ *I.Files Teaching Tips*

CONNECT TO UNIT CONTENT

We recommend using the Investigation Packs in one of two ways.

- Unit Support: Each Investigation Pack addresses an important aspect of the unit it accompanies. This activity is meant to complement the other unit materials while providing students with deeper scientific content. Before using the Investigation Pack, you might have students read the *Nonfiction Book* associated with the unit. Or instead, the pack can be used at the beginning of the unit in order to spark interest in the subject matter.
- Stand-Alone Close Read Activity: You can use the *I.Files* for a close reading activity before or after introducing other unit materials.

BEFORE THE ACTIVITY

1. Invite students to share experiences they have had with the subject matter of the Investigation Pack.
2. Read the Key Question as a class to set a purpose for reading. Make sure students understand what the question is asking.
3. On the *I.File Response Sheet*, have students write what they *think* the answer is in the My First Answer section, based on their prior knowledge. Now is a good time to review unfamiliar vocabulary.

Grouping Alternatives

Have students work in Investigation Teams (or "I.Teams") of four to six. Ideally, each student will read one *I.File*, and then the whole group will convene to discuss the pack of files. If using smaller groups, consider one of these approaches:

- Some students read more than one *I.File.*
- Pairs of students read and discuss two files. Then two or more pairs meet to discuss all the files in the pack.
- Each student reads just one file. Then the group reads all remaining files together.

Group Roles

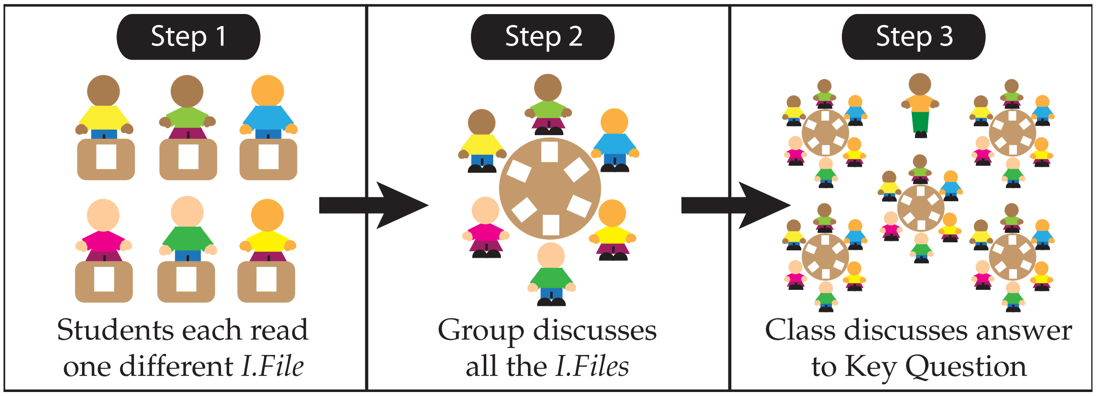
Consider assigning group roles to students, particularly a recorder and a discussion leader. Other roles might include a materials collector, a timekeeper, a reporter, and a fact checker.

DURING THE ACTIVITY

Have each student read an *I.File* and complete an *I.File Response Sheet*. While reading, students should record key vocabulary terms in the My Key Words and Definitions chart and attempt to define them in their own words using context clues. Provide dictionaries to help students define the words.

In the My Evidence section, instruct students to record details from their *own* reading that may help answer the Key Question.

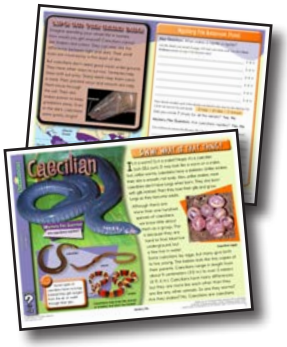
Now have students come together as a group and report on what they have learned. They should collaboratively fill out the group section (I.Team Evidence) of the *I.File Response Sheet*. This section provides space for details that are *definitely* true of all the files as well as space for details that only *might* be true. By analyzing which details are found in *all* the files, students will engage in scientific argument in order to come to an agreement on the answer to the Key Question. Invite groups to share their findings so the whole class can come to a consensus. Refer to the *I.Files Teaching Tips* to guide the discussion.



Students each read one different *I.File*

Group discusses all the *I.Files*

Class discusses answer to Key Question



Mystery File

After groups have answered the Key Question, ask each student to read the *Mystery File*. Using the worksheet on the back of the file, groups should first fill in the key details that were common to the *I.Files* they read. These can be copied directly from the left-hand I.Team Evidence section of the *I.File Response Sheet*. Then have them circle whether each detail is or is not true of the *Mystery File*. The *Mystery File* must match *all* the common key details in order for the answer to the Mystery File Question to be *yes*.

AFTER THE ACTIVITY

Invite groups to share their answers to the Key Question and the Mystery File Question. If groups disagree, encourage scientific argument, referring back to the *I.Files* for evidence. If groups didn't find all the key details listed in the *I.Files Teaching Tips*, share with them the ones they missed.

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SPECIAL NOTE: It is important that students come away with the correct answers to the Key Question and the Mystery File Question. Address any misconceptions that may have influenced students' answers (see *I.Files Teaching Tips*).

EXTENSIONS AND VARIATIONS

Consider these ideas to extend the usefulness of any Investigation Pack. Also see the I.Files Teaching Tips that accompany each set of I.Files for extensions and variations specific to that Investigation Pack.

- *Home Connection:* Using the "flipped classroom" approach, have each student read all the *I.Files* in an Investigation Pack for homework, completing a separate *I.File Response Sheet* for each file. Back in class, have students discuss the answers to the Key Question and the *Mystery File.*
- *Center Activity:* After the group activity, in which each student only read one *I.File*, place copies of the *I.Files* in centers around the room. Allow students to read the rest of the files from the pack to learn more about each topic.
- *ELL:* Consider these tips to help English Language Learners access the text:
  1. Provide vocabulary support by using a word wall.
  2. Review pronunciations with students before beginning the activity.
  3. Introduce any science words that have cognates in a student's native language.
  4. Pair an English Language Learner with a fluent reader of English and have them read the same *I.File* together.
  5. Allow students to define vocabulary terms in nonlinguistic fashion (drawings).
- *Arts:* In a science journal or on a separate piece of paper, students can create their own version of a picture or diagram from their *I.File* or draw a new one based on facts from their reading.
- *Technology:* For digital literacy practice, have students conduct supervised online research on the topics from their *I.Files*. Students can present their findings to the class using digital presentation software.
- *Writing/Arts:* Have students research and create a new *I.File* on a topic of their choice. Be sure the new *I.File* includes all the necessary shared details to include it with the others. Students may also add images, maps, graphs, math problems, and interesting sidebars.
- *Field Trip/Guest Speaker:* Take a class field trip or invite a guest speaker to help students learn more about the topics presented in the *I.Files*.

Properties of Stars

Name ______________________________ Date ______________

Others on my I.Team ____________________________________

Title of *I.File* ______________________________________

Key Question

What makes a star a star?

My First Answer

Explain what you *know* or *think you know* about the answer to the Key Question <u>before</u> reading any of the *I.Files.*

____

____

My Key Words and Definitions

List five words from your *I.File* that are important for understanding the topic. Then write a definition for each one in your own words.

Word	My Definition
1.	
2.	
3.	
4.	
5.	

Name ______________________________ Date __________

My Evidence

List details from your *I.File* that may be important for answering the Key Question. Your details do not need to be written in complete sentences.

I.Team Evidence

Use as many lines as you need or use more paper.

List all the details you found in every *I.File* your team read. Use only these details to answer the Key Question.

List details that *might* be true of all the *I.Files,* but you would have to learn more to know for sure. Do not use these details to answer the Key Question.

I.Team Answer

Use complete sentences to answer the Key Question.

What makes a star a star?

BLUE SUPERGIANT

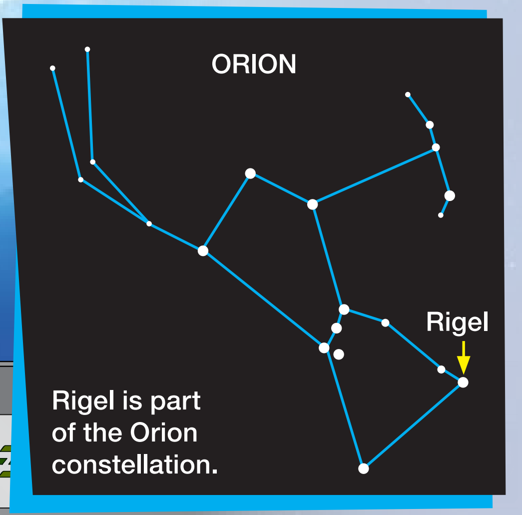
A blue supergiant isn't just bigger than our Sun. It's also much hotter!

BIGGEST AND BRIGHTEST

"We're headed toward Rigel," Captain Gamma said. "Aim for the brightest star you see."

Kara aimed the *Stella* toward a shining point in the vast blackness. "We must be close," she said, raising *Stella*'s protective shield. "It's already too bright to look at. This star is huge!" She brought the *Stella* closer so the Star Reader could take measurements. She felt the controls straining against the enormous gravity.

"Its diameter is 74 times the Sun's," Manolo calculated. "And it's 40,000 times brighter! We can't get much closer."



Rigel is part of the Orion constellation.

"We don't want to stay long, either," Captain Gamma said. "This is a blue supergiant. It has a short life span, so it might be unstable. We don't want to be around when this thing becomes a supernova."

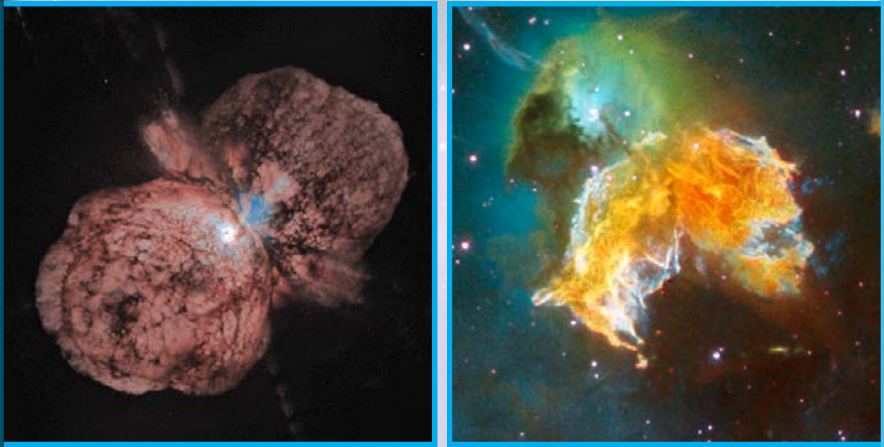
"Wow! It's 18 times the mass of the Sun, and its temperature is over 10,700 degrees Celsius!" Kara said. "Too hot for me." She leaned hard against the controls and steered the *Stella* back out toward the blackness.

Credits: © Science Photo Library/Alamy

Supernova

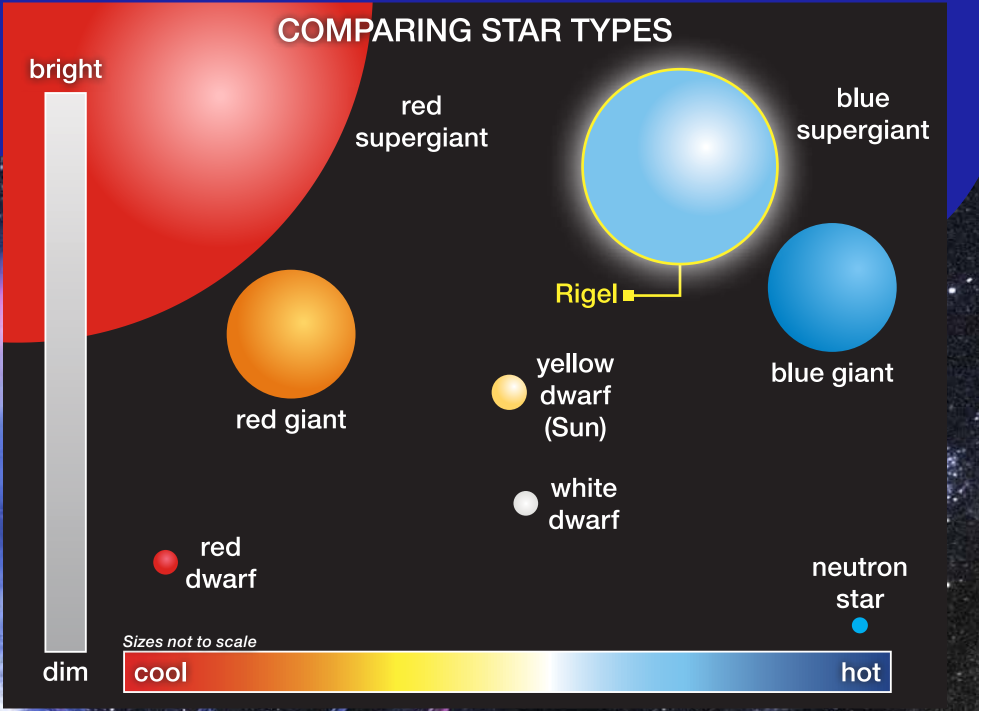
A star might seem like it will last forever, but it won't. In fact, a blue supergiant star has a short life span compared to other stars. It will "only" exist for a few million years.

A star releases energy through nuclear fusion. The star burns up hydrogen as a hot bonfire burns up a log. When the fuel runs out, the star's core suddenly collapses due to gravity. Its outer shell explodes in a fiery blast. This explosion is called a *supernova.* It's one of the most powerful explosions in the universe. A supernova releases more energy in one week than the Sun releases over its entire life!



Supernovas are so bright that scientists can spot them in galaxies millions of light-years from Earth.

COMPARING STAR TYPES



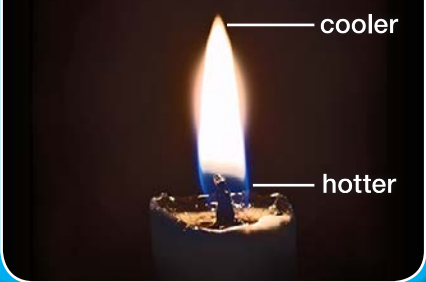
Rigel is a blue supergiant, which is one of the brightest star types in the universe. It looks blue because of its high temperature.

Wowser!

A massive blue supergiant has a life span of about three *million* years. That may sound like a long time, but the longest-lived stars, red dwarfs, can exist for nine *trillion* years!

Do You Know?

The hottest part of a candle flame is blue, while the white part is cooler. Similarly, a blue supergiant looks blue because it is so hot.



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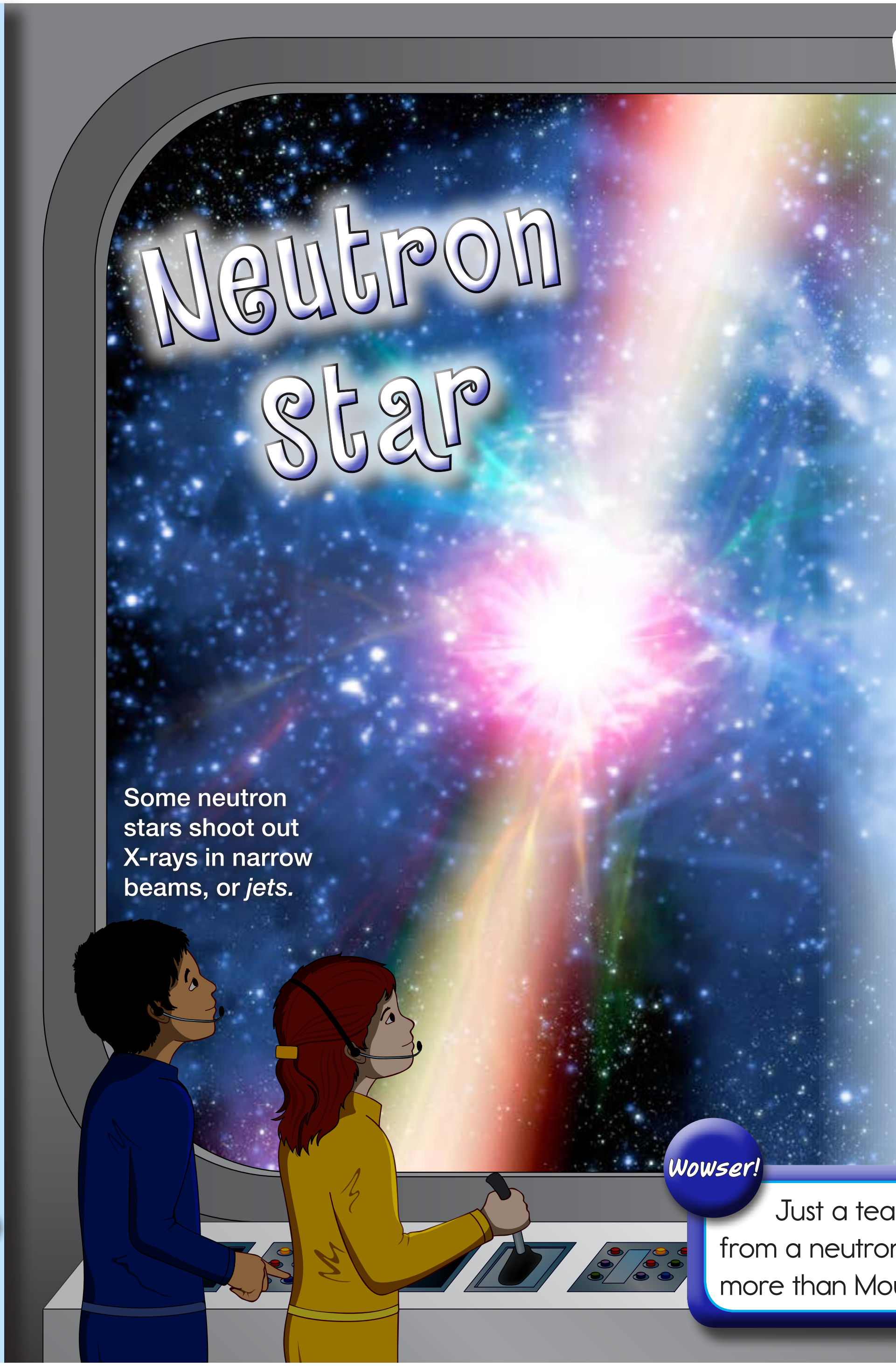
Neutron Star



Some neutron stars shoot out X-rays in narrow beams, or *jets.*

STRANGE MATTER

Manolo awoke from a long interstellar sleep. Captain Gamma and Kara were already up and busy. "What are we looking at?" he yawned.

"LGM-1," said Captain Gamma, pointing at a barely visible dot of light.

"This thing must have a glitch," Laura muttered at the Star Reader. "It's telling me that this star has a mass 1.5 times that of the Sun, but its diameter is barely 2 kilometers."

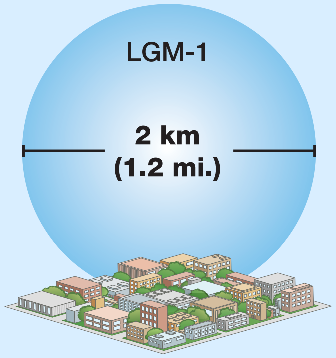
"Oh, it's a neutron star," Manolo chimed in, still drowsy. "When an enormous star runs out of fuel, its core completely collapses under its own gravity," he explained. "The gravity is so powerful that even the electrons and protons inside atoms crush together, making a ball of solid neutrons. It's like one giant atomic nucleus the size of my neighborhood back on Earth."

"It's not giving off much visible brightness, but it's blasting out dangerous X-rays," Captain Gamma warned. "This star's temperature is off the charts. We shouldn't stay long."

Manolo stared out the window as the *Stella* sailed away from the neutron star. "But I just woke up!"

Wowser!

Just a teaspoon of matter from a neutron star weighs more than Mount Everest!

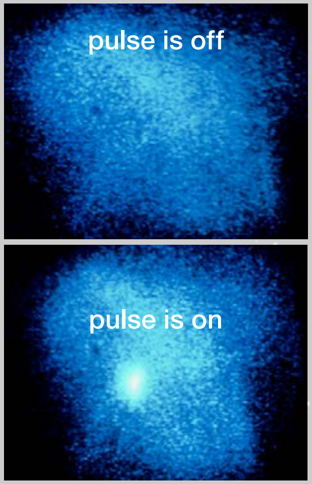


The neutron star LGM-1 is only as wide as a few city blocks.

Credits: © Science Photo Library/Alamy

LITTLE GREEN MEN?

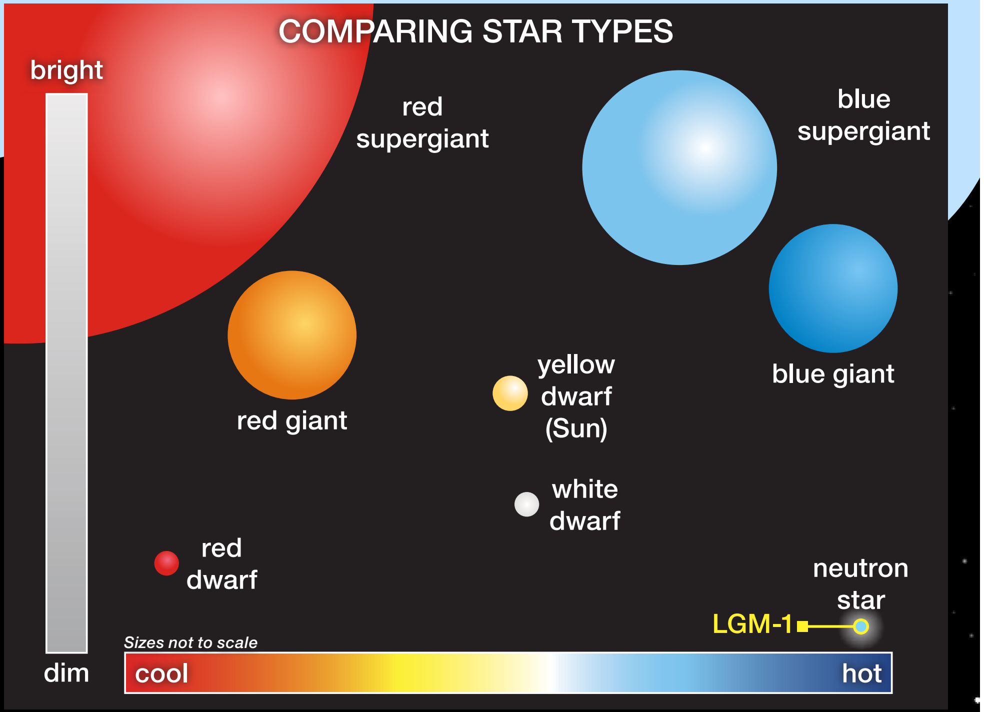
The star LGM-1 is a special kind of neutron star called a *pulsar*. A pulsar is a rotating neutron star that shoots out a narrow beam of energy, like the spinning light in a lighthouse. From Earth, this spinning light seems to flash at a steady rhythm, or "pulse." The star will spin for most of its life span—up to 300 million years! It releases energy left over from nuclear fusion that took place earlier in the star's history.



Rapidly spinning neutron stars seem to pulse.

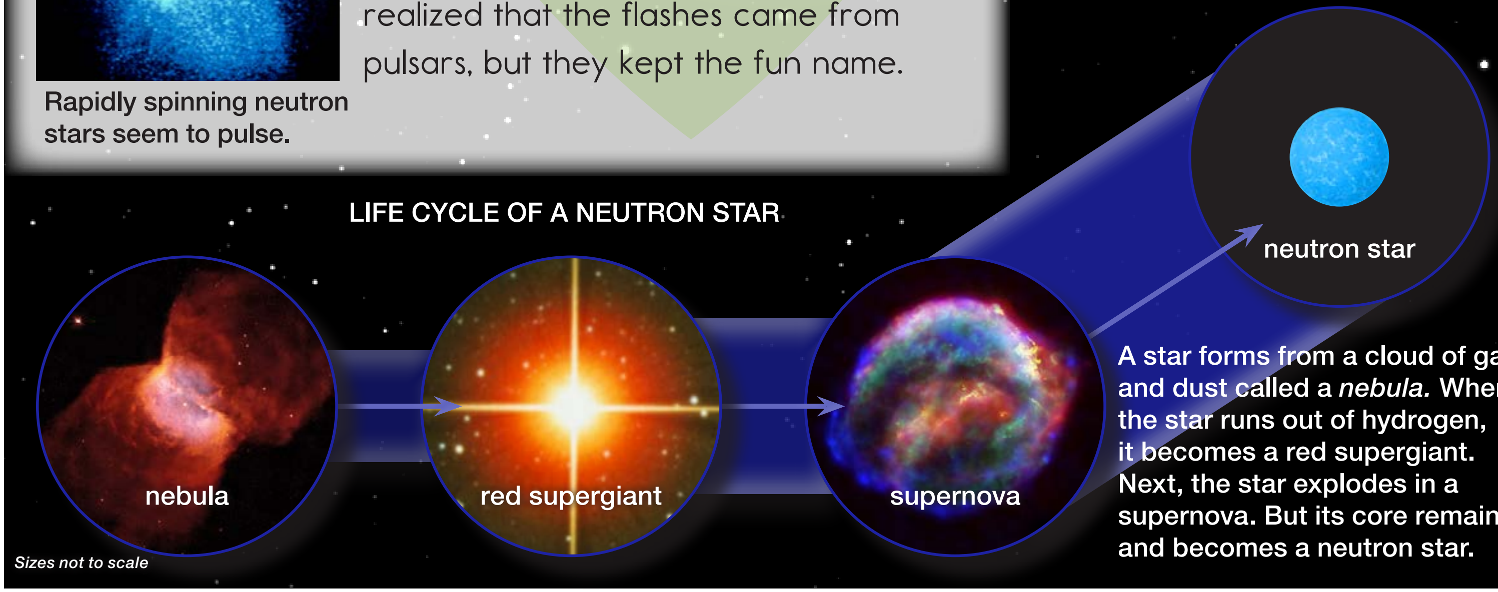
When astronomers first spotted one of these pulsing beams, they were baffled by what could make such perfectly steady flashes. Some scientists wondered if the flashes were signals from an alien civilization. They jokingly named the flashing object "LGM," which stands for "little green men." Scientists quickly realized that the flashes came from pulsars, but they kept the fun name.

COMPARING STAR TYPES



Neutron stars, such as LGM-1, look blue because they have very high temperatures. They release most of their energy as invisible radiation, so they are not very bright.

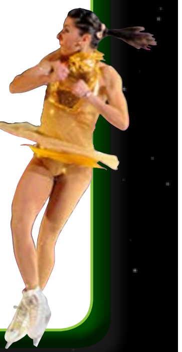
LIFE CYCLE OF A NEUTRON STAR



A star forms from a cloud of gas and dust called a *nebula*. When the star runs out of hydrogen, it becomes a red supergiant. Next, the star explodes in a supernova. But its core remains and becomes a neutron star.

Wowser!

When a giant star becomes a neutron star, it gets much smaller. As it shrinks, it spins faster and faster, like a skater pulling in her arms as she twirls. Some neutron stars get so small that they can spin in less than a second!



Credits: left: © Smithsonian Institution/Science Source; life cycle diagram left to right: courtesy of NASA/Massimo Stiavelli/ STScI; © Royal Observatory, Edinburgh/Science Source; courtesy of NASA; courtesy of NASA/CXC/ Southampton/W. Ho et al.; bottom right: © Franco Ricci/Dreamstime.com; background main: courtesy of NASA/JPL/Space Science Institute; background left inset: © iStockphoto.com/Arno Spaansen

RED DWARF

An artist's depiction of Gliese 581 and some of its planets.

Do You Know?

Scientists find distant planets by looking for wobbly stars. Stars wobble when they are tugged by the gravity of a nearby planet.

SMALL AND DIM

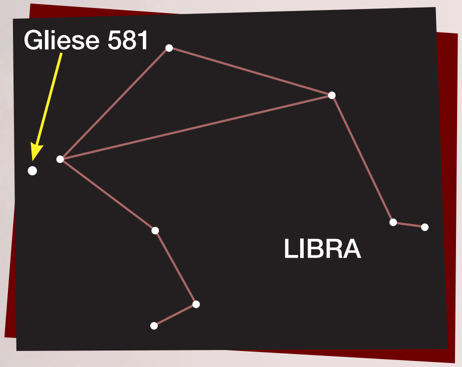
Kara steered the *Stella* where Captain Gamma pointed, but she didn't see anything. "Is *that* it?" she asked, finally spotting a faint red disk. Her Star Reader told her that this star was only about one-third the mass and one-third the diameter of the Sun.

"Its surface temperature is about 3,200 degrees Celsius," Manolo noted. "But the Sun is 2,000 degrees hotter than that! These little red dwarfs aren't very impressive."

"Welcome to Gliese 581," Captain Gamma announced as they drew closer to the star. "Look closely," he said. "Even a red dwarf like Gliese can surprise you."

Manolo squinted as he looked out the window. Gliese 581 was not very bright, so at first he saw just the star. Then he noticed a few lumps floating in the blackness. "It has planets!" Manolo shouted. "I count four, and there might be more, but Gliese is too dim to light them up."

Kara kept the *Stella* near Gliese for a long time, staring in wonder at the dark disks orbiting the star. "Planets . . ." she wondered aloud. "Maybe there's one like Earth!"



Gliese 581 isn't very bright, so you'll need a telescope to see it. Look for it near the constellation Libra.

Credits: © Mark Garlick/Science Source

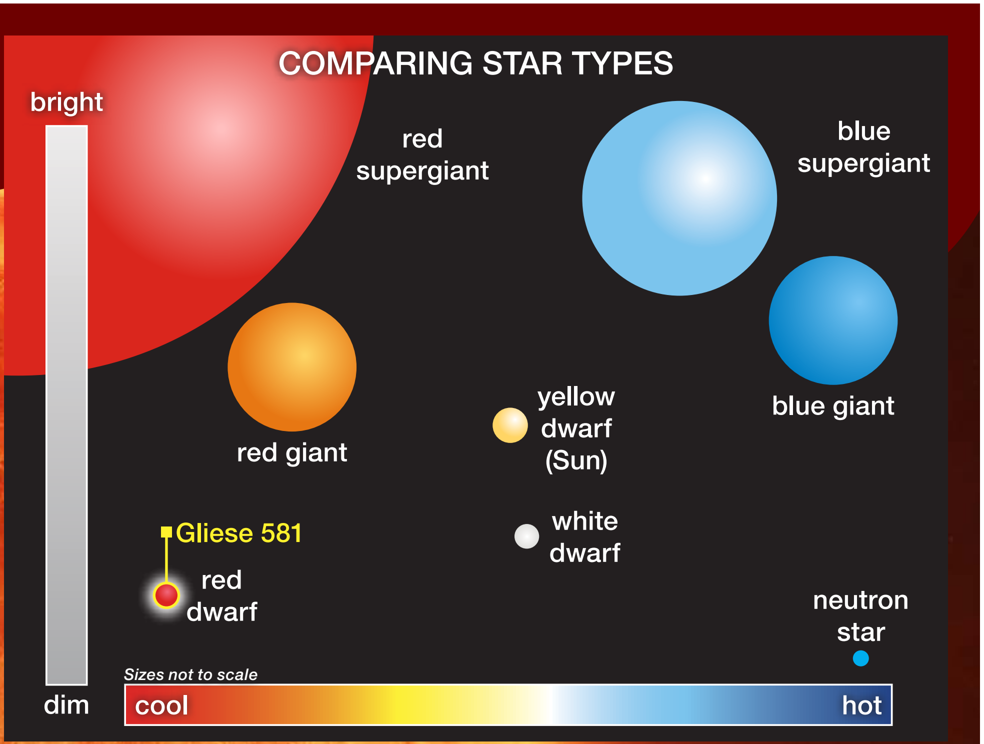
Live Long and Stay Cool

A star's life span depends on its mass; small stars live longer than large stars do. Red dwarfs have the longest life span of any star type. They can burn for *trillions* of years! That's because red dwarfs don't have much mass.

Red dwarf stars release energy through nuclear fusion. Their gravity crushes hydrogen until it turns into helium. But red dwarfs have weak gravity because of their small mass. As a result, they can only crush a little bit of hydrogen at a time.

These stars don't have a lot of nuclear fusion going on at once, so they never get as hot or bright as other stars. Even though red dwarf stars don't have much hydrogen, they can keep burning it for a long time without running out.

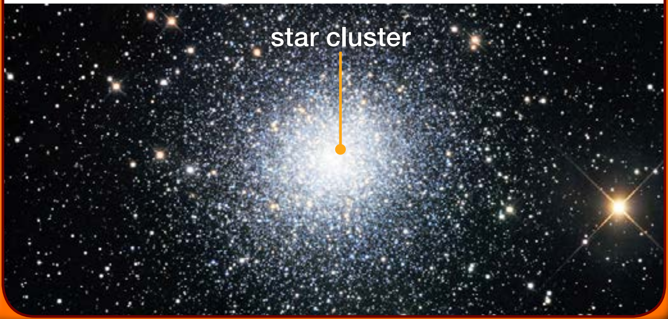
COMPARING STAR TYPES



Gliese 581 is a red dwarf star. It looks red because of its low temperature. Red dwarfs are not very hot or bright compared to other star types.

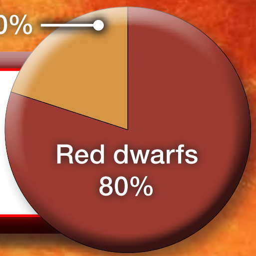
Do You Know?

Stars often form near each other at about the same time, creating a *cluster*. If all the large stars in a cluster have burned out, leaving only red dwarfs, the cluster is probably old.



Wowser!

Scientists estimate that 80% of all stars in the Milky Way galaxy are red dwarfs. There may be 60 million red dwarfs in our galaxy alone!



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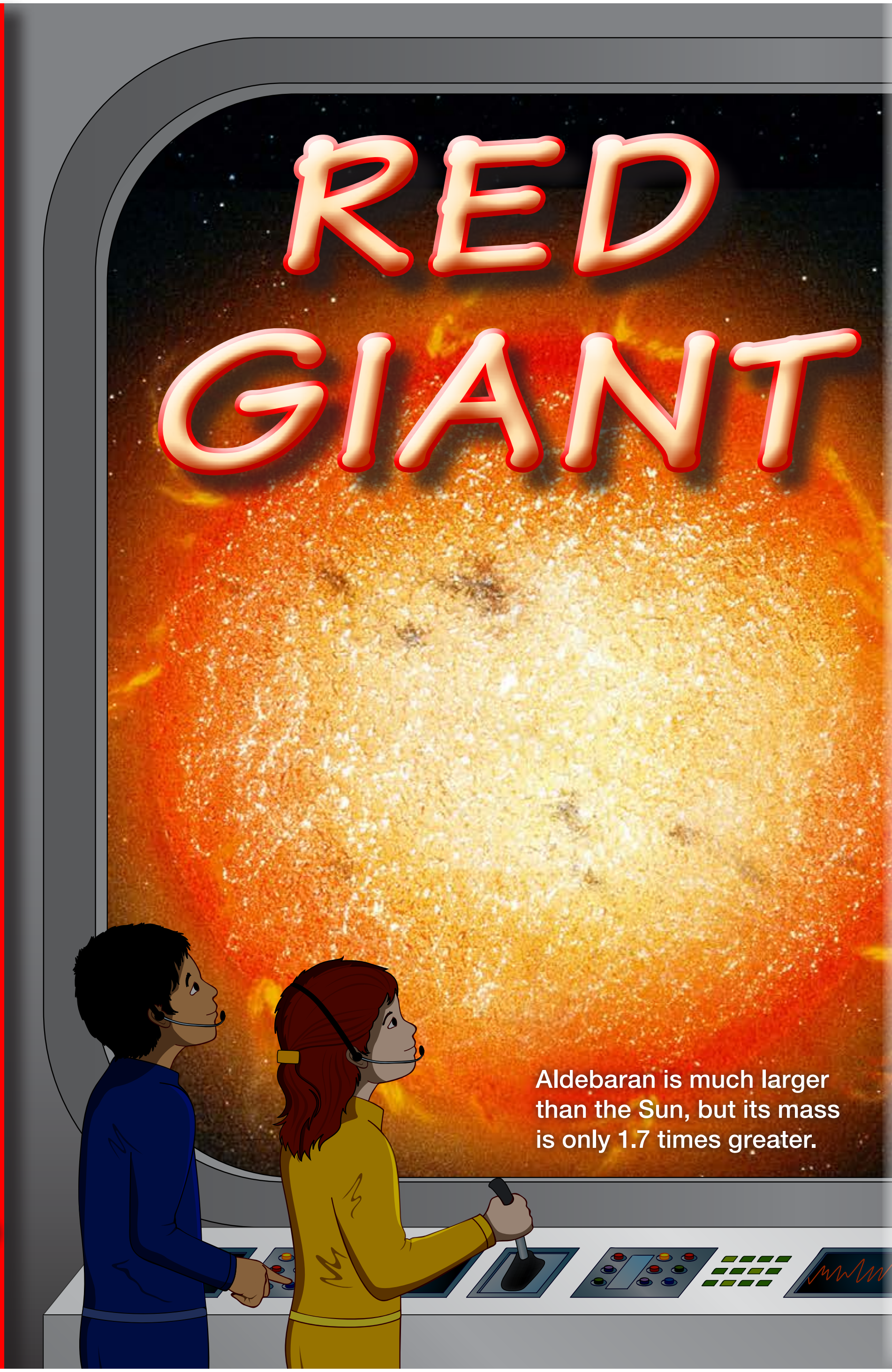
RED GIANT



Aldebaran is much larger than the Sun, but its mass is only 1.7 times greater.

BIG RED

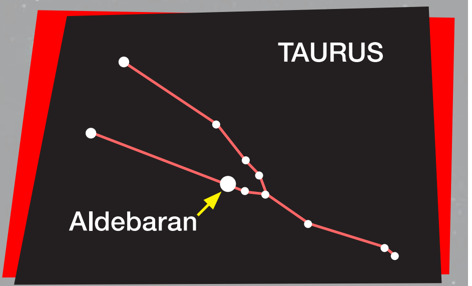
"Our next stop will be Aldebaran," Captain Gamma announced. The crew looked up excitedly.

Kara reset the Star Reader. Where had she heard that unusual name before? Then she remembered—Aldebaran (all-DEB-er-on) was one of the brightest stars in Earth's sky.

Soon the *Stella* was bathed in red light. "This star is enormous!" Manolo shouted. "It's 44 times wider than the Sun, but its temperature is much cooler. How does such a cool star shine so brightly?"

Captain Gamma turned off the cabin lights and switched on a small reading lamp. "This light is bright, but it's very small," he explained, shining the light at the floor. Then he turned on the cabin light, which lit up the whole deck. "The cabin light isn't as bright, but it's much larger, so it puts out more total light."

"Sounds like a red giant," said Kara. "When stars with a low mass run out of hydrogen fuel, they expand to an enormous size. They look bright from far away." Kara wondered if people on Earth realized that one of their brightest stars was a cool, aging giant.



Aldebaran is the brightest star in the constellation Taurus (the bull).

Credits: © John R. Foster/Science Source

THE END OF THE SUN

Aldebaran has only a little more mass than the Sun. So why is it so large?

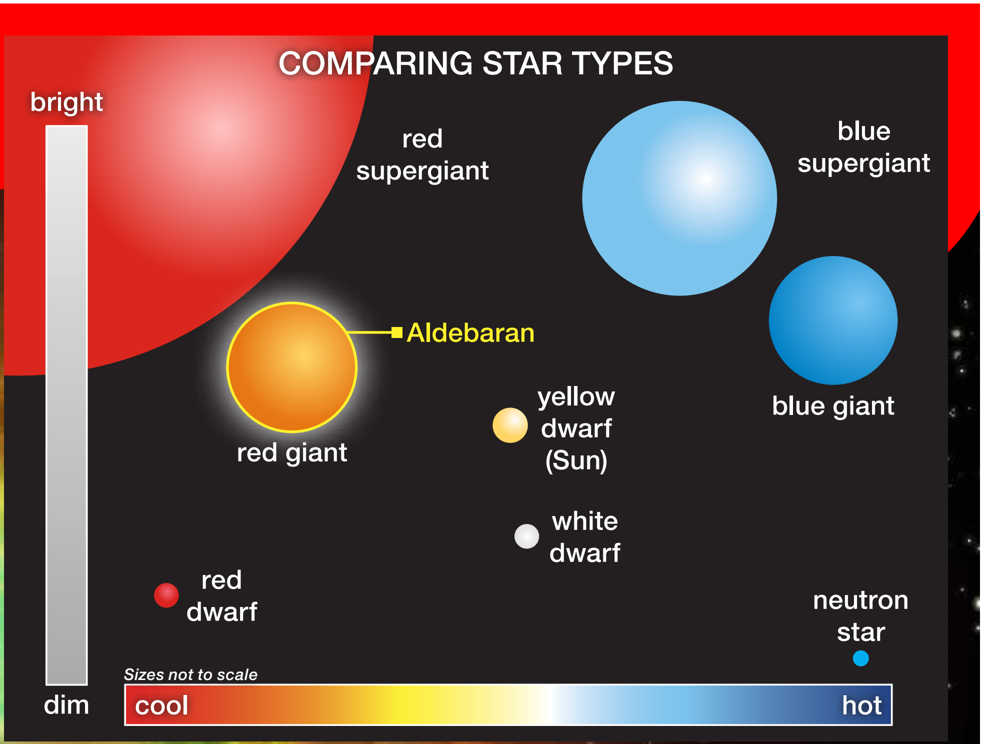
A star releases energy through nuclear fusion. This process turns hydrogen into helium. But over time, the star burns up all its hydrogen, like a car running out of gas. When this happens, the star expands outward. It can grow to one hundred times its starting diameter! The star is now a red giant. It has a life span of "only" a few million years.

Someday, our Sun will run out of hydrogen and become a red giant. It will cool down and expand. The Sun will get so big that it will swallow up Mercury and Venus, and maybe even Earth. But don't worry—that won't happen for at least five billion years!

Math Moment

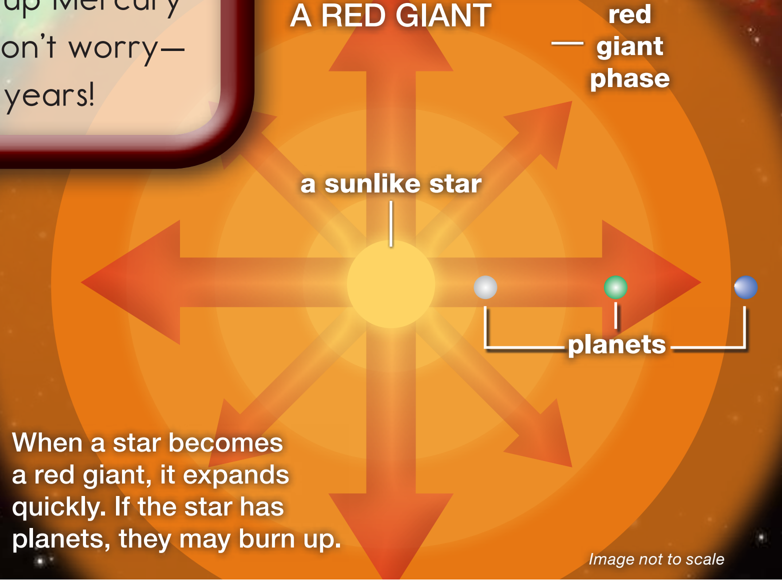
The Sun is about 1.4 million kilometers wide. When it becomes a red giant, it could be 100 times wider. How wide will it be then?

COMPARING STAR TYPES



Aldebaran is a red giant. Red giants are cool, which is why they look red. They are also bright.

BECOMING A RED GIANT



When a star becomes a red giant, it expands quickly. If the star has planets, they may burn up.

Eventually, gravity can no longer hold a red giant star together, and the star loses its outer layers. The clouds of gas and dust stay around the fading star. They form a *planetary nebula.*

Credits: bottom right: courtesy of NASA/ESA and The Hubble Heritage Team STScI/AURA; background: © Science Photo Library/Superstock

WHITE DWARF

Sirius B isn't visible from Earth. The much larger Sirius A outshines it.

Do You Know?

Binary stars, or pairs of stars orbiting each other, are fairly common. As many as half the stars in the Milky Way might be binary stars!

THE WHITE-HOT CORE

Manolo had seen Sirius many times. It's one of the closest stars to Earth. But as the *Stella* flew closer, he spotted something unexpected. "Kara, aim the Star Reader at that little white dot next to Sirius," he ordered.

Kara tapped the screen and furrowed her brow. "It's a star with about the same mass as the Sun," she said. "But its diameter is only as big as Earth's. How can that be?"

"Ah, that's Sirius B!" Captain Gamma proclaimed. "Sirius is actually two stars orbiting each other—Sirius A and B."

"Wow! This star is unbelievably hot—25,000 degrees Celsius!" Kara exclaimed.

"It must be a white dwarf," Manolo said in awe. "It's the core of an old star that burned up all its hydrogen.

"If there's no hydrogen fuel left, why is it so hot and bright?" Kara asked.

"It has energy left over from nuclear fusion," Manolo explained. "It's like when a car engine stays hot even after the car is turned off. Sirius B will stay hot for billions of years."

White dwarfs can be as small as Earth. But they have as much mass as the Sun!

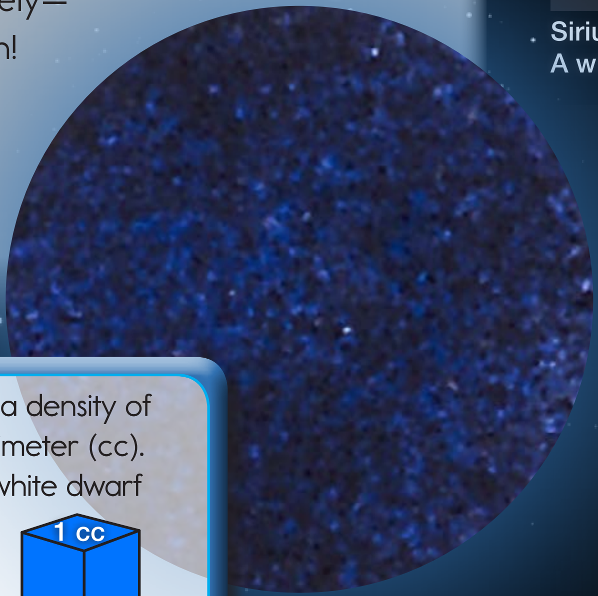
Credits: left: courtesy of NASA, ESA and G. Bacon (STScI); right: courtesy of ESA and NASA

Black Dwarfs

When a star has used up all its hydrogen fuel, it expands rapidly. Eventually, it collapses under its own gravity and becomes a white dwarf. Although it's out of fuel, a white dwarf still shines brightly, like an electric burner that glows after you turn off the stove.

Like the electric burner, a white dwarf will eventually cool. However, a white dwarf has a long life span. In fact, it can take *hundreds of billions* of years to cool. What's left is a cold, dark object called a *black dwarf.*

Actually, black dwarfs only exist in theory. Scientists have never observed them because no white dwarfs have had the chance to cool completely—the universe isn't old enough! The universe is "only" 13.7 billion years old. So it will be a long time until any black dwarfs form.

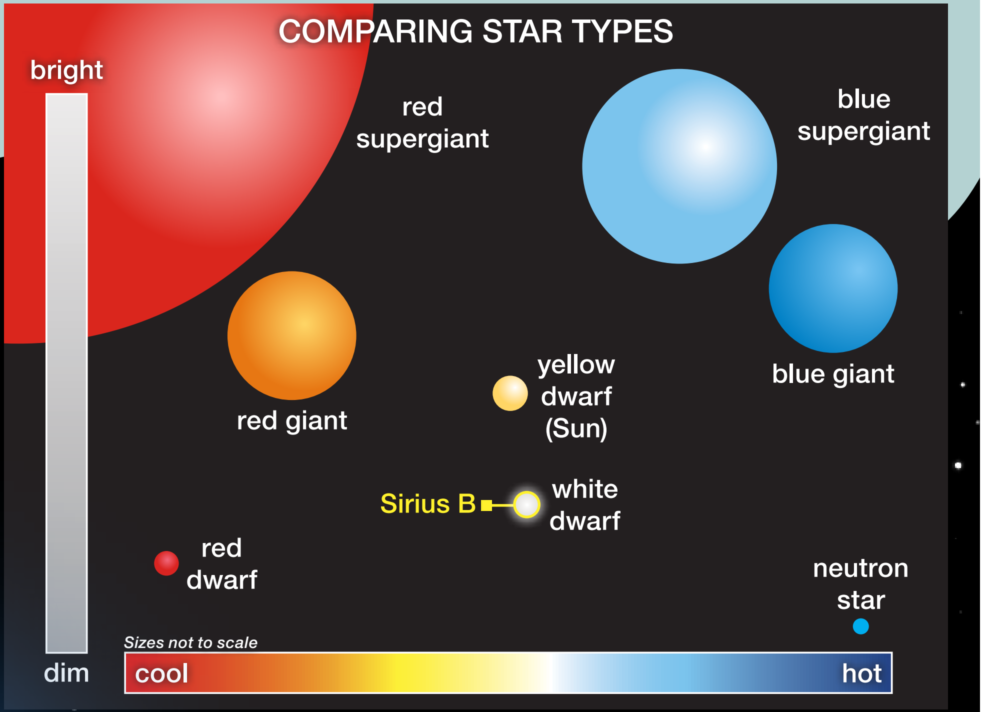


Math Moment

A white dwarf star has a density of 1,000 kilograms per cubic centimeter (cc). Imagine you have a block of white dwarf matter that's 108 cc in size, or about the size of a deck of cards. How much does your block of matter weigh?

1 cc

1 cc = 1,000 kg



Sirius B is a white dwarf star. It looks white because it is fairly hot. A white dwarf star isn't very bright compared to other star types.

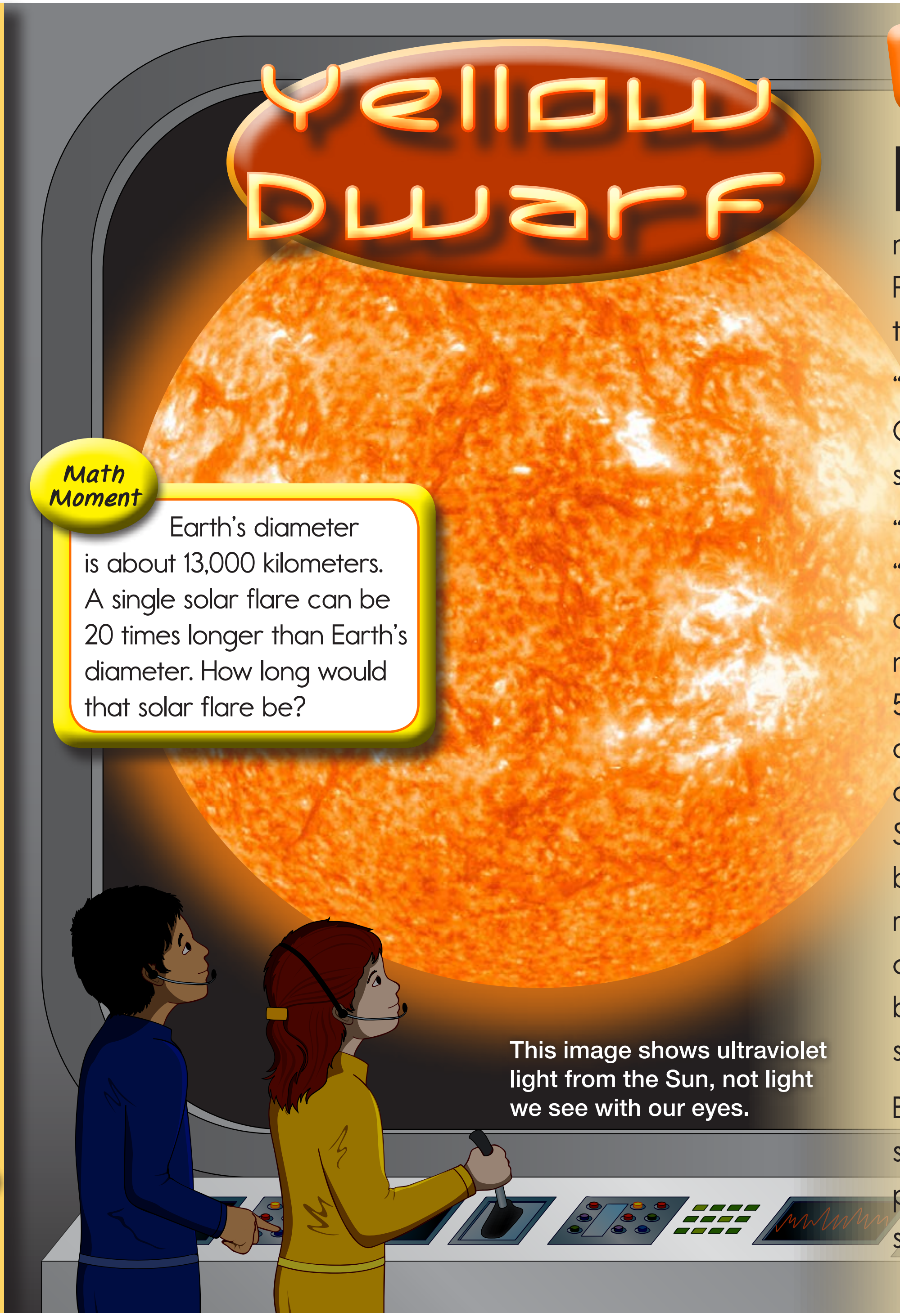
THE FUTURE OF THE SUN

First, the Sun (A) will become a red giant (B) and expand to 100 times its starting diameter. Then it will become a white dwarf (C) and collapse down to the size of Earth!

Image not to scale

Credits: left: © DK Images; background: courtesy of NASA/JPL/Space Science Institute

Yellow Dwarf



This image shows ultraviolet light from the Sun, not light we see with our eyes.

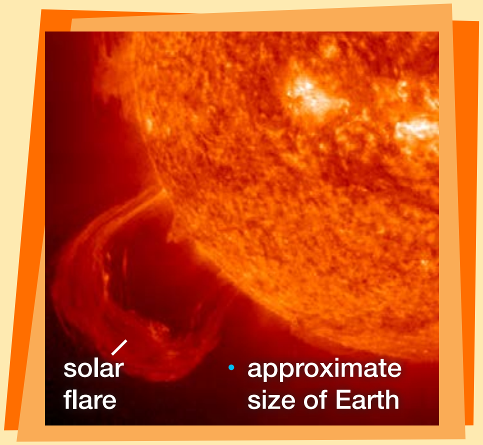
Math Moment

Earth's diameter is about 13,000 kilometers. A single solar flare can be 20 times longer than Earth's diameter. How long would that solar flare be?

OUR SUN

Kara gazed out the window of the *Stella* and saw a familiar sight. "The Sun!" she exclaimed. She recognized the bright yellow dwarf star. Her Star Reader told her that the Sun's diameter was about 109 times that of Earth's, but it looked even bigger up close.

"Let's go in close and catch the solar wind," Captain Gamma said. "We can use it to push us out of the solar system." Kara steered the *Stella* toward the Sun.



A solar flare is an explosion of hot gas from the surface of the Sun.

"Be careful!" cried Manolo. "The Sun may be a yellow dwarf, but it's still a giant nuclear furnace—it's over 5,500 degrees Celsius down there!" He had always thought of the Sun as a smooth disk, but up close it looked more like a bowl of boiling chili. Hot gas bubbled up between crusty sunspots. Solar flares erupted from the surface with plumes larger than Earth.

But Kara had already turned the *Stella* to catch the solar wind. "Here we go!" she said. A stream of invisible particles from the Sun helped push the ship out into space. The crew had more stars to see.

Credits: left: courtesy of SOHO (ESA & NASA)/EIT Consortium; right: courtesy of ESA/NASA/SOHO

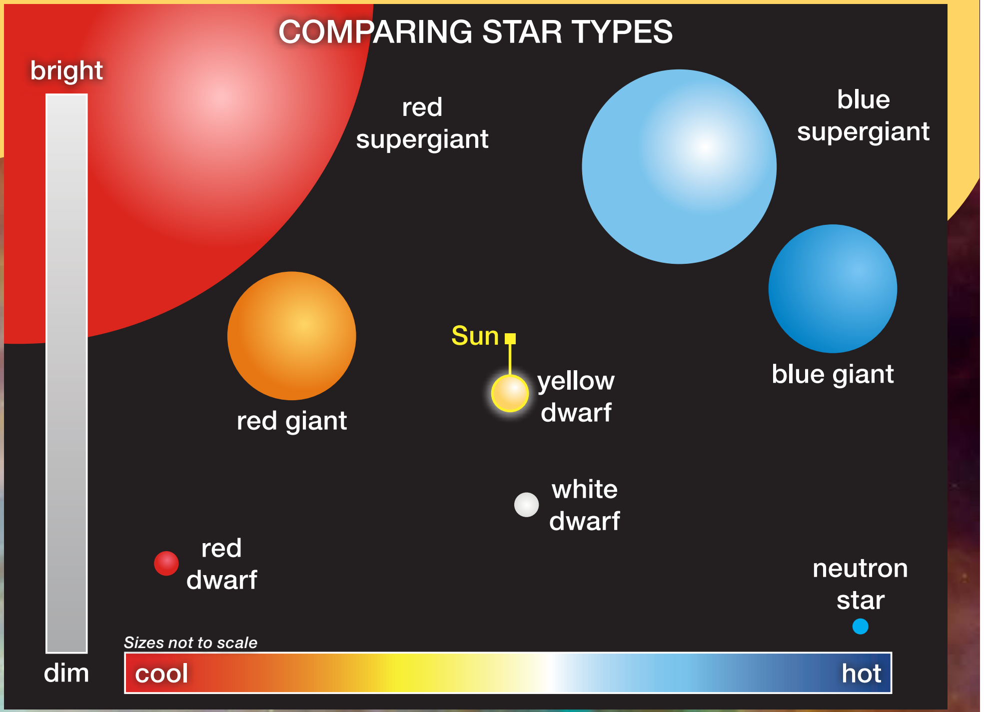
Lighting a Star

The Sun began to form about five billion years ago. Like all stars, it started out as a cloud of gas and dust. The gas was mostly hydrogen, with some helium. This wasn't exactly a *little* cloud. The Sun's cloud was bigger than our whole solar system!

Gravity drew the cloud in, squeezing and crushing the gas and dust. It squeezed the hydrogen atoms so tightly that their nuclei combined. The Sun was "born."

The Sun and other yellow dwarfs release energy through nuclear fusion. Most of this energy is given off as light and heat. When a yellow dwarf runs out of hydrogen, it expands and becomes a red giant. But don't worry! The Sun has enough hydrogen to last another five billion years. It will have a total life span of about ten billion years!

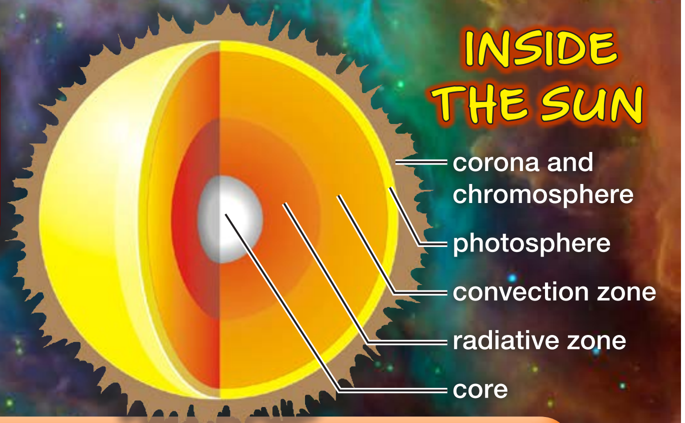

Stars form in towering clouds of gas and dust, like these.



The Sun is a yellow dwarf star. Yellow dwarfs are yellow because of their moderate temperature. They are also fairly bright.

Wowser!

Over 99% of all the mass in our solar system is in the Sun itself!



Do You Know?

Astronomers use the mass of the Sun, called M, as a unit of measurement. For example, a star with ten times the mass of the Sun has a mass of 10M.

Credits: left: courtesy of NASA, ESA, STScI, J. Hester and P. Scowen (Arizona State University); background: courtesy of NASA/JPL-Caltech/STScI

Mystery File Question

Is a black hole a star?

A black hole's gravity is so powerful that it bends light around it.

Wowser!

Some astronomers estimate that black holes have a life span of more than a *vigintillion* years! That's a one followed by sixty-three zeroes!

NO ESCAPE

The crew of the *Stella* had finished its long star tour. Kara turned the vessel toward the center of the Milky Way. Here, the stars were clustered so closely together that they looked like a solid disk of light.

"I just found our path home," Kara announced as she steered toward an empty space with no brightness at all.

"No!" Manolo shouted. Kara felt a huge tug of gravity. Just in time, she steered the *Stella* up and away from the strong force. They stared at the strange, empty spot. What could have such strong gravity but not be visible?

"It's a black hole," Captain Gamma explained. "Black holes form when enormous stars collapse. Their gravity is so strong that even *light* can't escape." But no nuclear fusion is going on inside.

Kara looked at her Star Reader. "Weird. This black hole has a mass over four *million* times that of the Sun, but its diameter is less than *forty* times the Sun's," she said.

"It's too dangerous to get closer," Captain Gamma warned. "We'll just send a probe to investigate. Then let's head home."

Astronomers believe most galaxies have black holes at their centers.

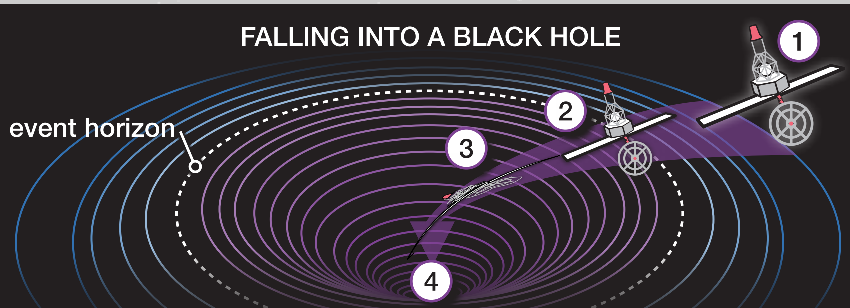
Credits: left: courtesy of NASA and G. Bacon (STScI); right: © Lynette Cook/Science Source

LONG GONE

The crew of the *Stella* watched their space probe, the *Diver*, sail toward the center of the black hole. From the *Stella*, the *Diver* appeared to slow down and then freeze, as if time had stopped. From the probe, everything seemed normal. It continued to take readings, noting that the temperature was near absolute zero—the lowest possible temperature.

Then the enormous gravity of the black hole began stretching the *Diver*. It pulled the probe into a long, thin strand, like spaghetti. Then the probe disappeared into the blackness. All the crew of the *Stella* could do was wave goodbye.

FALLING INTO A BLACK HOLE



1. Outside the event horizon, a spaceship can safely orbit the black hole.
2. Gravity holds light in one place. From far away, objects appear to stop moving.
3. Gravity pulls unevenly on objects, stretching them out. This process is called *spaghettification.*
4. Objects that get pulled into the black hole are crushed.

Mystery File Response Sheet

Key Question: *What makes a star a star?*

List the details you found in <u>every</u> *I.File* that your team read. Use the **I.Team Evidence** section of your *I.File Response Sheet.*

______________________________ T F ?

______________________________ T F ?

______________________________ T F ?

______________________________ T F ?

______________________________ T F ?

______________________________ T F ?

Now decide whether each of the details you listed is also true for the *Mystery File.* Circle one answer for each detail: **T** = true **F** = false **?** = not sure

Did you circle **T** (true) for all the details? **Yes No**

Mystery File Question: *Is a black hole a star?* **Yes No**

Use evidence to answer the Mystery File Question. Write in complete sentences.

____

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Credits: background: courtesy of NASA/JPL/Space Science Institute

Properties of Stars

This Investigation Pack focuses on the properties of various types of stars.

KEY QUESTION SUGGESTED RESPONSES

Key Question

What makes a star a star?

List all the details you found in every *I.File* your team read. Use only these details to answer the Key Question.
It has mass.
It has a diameter.
It has a temperature (or color).
It has brightness.
It has a life span.
It releases energy through nuclear fusion.

I.Team Answer

A star has mass and a diameter. It has color, which is determined by its temperature, and it has brightness. A star also has a life span and releases energy through nuclear fusion.

Additional Information for Teachers

Stars do not all have the same mass, diameter, temperature (or color), brightness, and lifespan. However, all stars can be described by these properties. Additionally, all stars release energy through nuclear fusion. Stars are masses of luminous (light-producing) gas. They form when gravity crushes the gas together so powerfully that hydrogen begins to fuse into helium, releasing energy in the form of light, heat, and radiation. Eventually, stars burn up all their hydrogen fuel and, after a period of instability, either collapse or explode.

ENRICHING VOCABULARY

These terms appear in one or more student files. You may want to introduce them before students begin reading the I.Files.

atom	the smallest part of an element, consisting of protons, neutrons, and electrons
cluster	a close group of similar objects
galaxy	a large collection of planets, gas, dust, and millions or billions of stars, bound together by gravity
gravity	the natural force that pulls objects toward each other, such as objects being pulled toward Earth or other large celestial bodies
nuclear fusion	the process by which the nuclei of atoms are joined together to create energy
nucleus	the positively charged central region of an atom, consisting of protons and neutrons, and containing most of the atom's mass
pulse	a short burst of energy

MISCONCEPTIONS

Use this section as a resource for more information about stars and to clarify the content for students if misconceptions arise.

Q: *Do stars with a high mass also have a large diameter?*

A: Not necessarily. *Diameter* describes how wide an object is, and *mass* is the amount of matter in an object. For example, a bowling ball and a soccer ball are about the same diameter, but they have very different masses. Stars with the same mass can have different diameters, and stars with the same diameter can have different masses.

Q: *Are hot stars always the brightest?*

A: No. Two factors determine the brightness of a star: its diameter and its temperature. If two stars have the same diameter, the one with the higher temperature will be brighter. However, a large, cool star, such as a red giant, might shine more brightly than a small, hot star, such as a neutron star, because it has more surface area.

Additionally, stars that are closer to Earth *appear* brighter in our night sky. Astronomers call this measurement *apparent brightness.* Scientists can also calculate how bright stars would be if they were all the same distance from Earth. They call this measurement *absolute brightness.*

Q: *Are stars that look close together in the night sky actually near each other?*

A: Not necessarily. Imagine looking across a wide field at two trees. From one end of the field, the trees may look close together. But one tree may actually be halfway across the field, while the other is on the far side of the field. Similarly, stars that appear close together from Earth may in fact be very far apart.

Q: *Is the Sun the biggest star in the universe?*

A: No. The Sun is not the biggest star, but it's not the smallest, either. The Sun looks big and bright to us because it is much closer to Earth than any other star. The Sun is near the middle of the range for both star size and brightness. Giant stars can be many times the mass and diameter of the Sun. However, the majority of stars are much smaller and dimmer than the Sun.

Q: *Stars have life spans, so are they living things?*

A: No. Stars are glowing balls of gas. However, astronomers often use terms such as *life span* and *life cycle* when referring to these nonliving objects. A star's *life span* is the approximate number of years a star is expected to exist. Life span is determined by a star's mass; the more massive a star, the shorter its life span. Most stars go through a predictable series of star types—called a *life cycle.*

Q: *Will the Sun be around forever?*

A: No. The Sun is about halfway through its approximately ten-billion-year life span. It is a yellow dwarf. In another five billion years, it will expand and enter its red giant phase. As a red giant, it will expand and burn up Mercury, Venus, and possibly Earth. Then it will shrink down and become a white dwarf. It will ultimately continue to cool until it is a black dwarf.

Q: *Do objects get pulled into black holes from far away?*

A: No. Only objects that cross the event horizon (the boundary around a black hole beyond which nothing can escape) get pulled into a black hole. Outside the event horizon, a black hole acts like any object that has gravity. A spaceship could conceivably orbit a black hole just as it orbits Earth.

Math Moment Solutions

In the Red Giant *I.File*, the following Math Moment appears on page 2:

Math Moment

> The Sun is about 1.4 million kilometers wide. When it becomes a red giant, it could be 100 times wider. How wide will it be then?

To solve the problem, multiply the diameter of the Sun, 1.4 million kilometers, by 100:

1.4 million km x 100 = 140 million km

When the Sun becomes a red giant, it will be about **140 million kilometers** wide.

◆

In the Yellow Dwarf *I.File*, the following Math Moment appears on page 1:

Math Moment

> Earth's diameter is about 13,000 kilometers. A single solar flare can be 20 times longer than Earth's diameter. How long would that solar flare be?

To solve the problem, multiply Earth's diameter, 13,000 kilometers, by 20:

13,000 km x 20 = 260,000 km

A solar flare that is 20 times longer than Earth's diameter would be **260,000 kilometers** long.

TIP: If students need help working with large numbers (such as 13,000 x 20), suggest that they first focus on multiplying 13 by 20, and then express that answer (260) in thousands.

◆

In the White Dwarf *I.File*, the following Math Moment appears on page 2:

Math Moment

> A white dwarf star has a density of 1,000 kilograms per cubic centimeter (cc). Imagine you have a block of white dwarf matter that's 108 cc in size, or about the size of a deck of cards. How much does your block of matter weigh?

To solve the problem, multiply the volume of the block, 108 cubic centimeters, by the density, 1,000 kilograms/cubic centimeter:

108 cc x 1,000 kg/cc = 108,000 kg

A block of white-dwarf matter the size of a deck of cards would weigh **108,000 kilograms**!

MYSTERY FILE SUGGESTED RESPONSES

Use the completed sample Mystery File Response Sheet and further explanation below to assess students' responses on page 2 of the Mystery File.

Mystery File Response Sheet

Key Question: *What makes a star a star?*

List the details you found in <u>every</u> *I.File* that your team read. Use the **I.Team Evidence** section of your *I.File Response Sheet.*

It has mass. [✓ T] F ?

Black holes have mass.

It has a diameter. [✓ T] F ?

Black holes have a diameter at their event horizon.

It has a temperature (or color). [✓ T] F ?

Black holes have a temperature of absolute zero and appear black.

It has brightness. T [✓ F] ?

Black holes have no brightness.

It has a life span. [✓ T] F ?

Black holes have an extremely long life span.

It releases energy through nuclear fusion. T [✓ F] ?

Black holes do not release energy. Energy cannot escape from black holes.

Now decide whether each of the details you listed is also true for the *Mystery File.*

Circle one answer for each detail: T = true F = false ? = not sure

Did you circle **T** (true) for all the details? Yes [✓ No]

Mystery File Question: *Is a black hole a star?* Yes [✓ No]

Use evidence to answer the Mystery File Question. Write in complete sentences.

Black holes are not stars. They do not release any energy through nuclear fusion, and they are not bright like stars.

Black Hole

Additional Information for Teachers

Black holes form when gravity crushes a mass into a single point with an infinite density. This usually, but not always, happens when super-massive stars collapse at the end of their life span. Because nothing can escape a black hole, not even electromagnetic radiation, black holes do not emit light or heat. As a result, scientists estimate their temperature to be absolute zero—the lowest temperature possible.

EXTENSIONS AND VARIATIONS

- *Guest Speaker:* Invite an astronomer to visit your class to speak about local stargazing opportunities.
- *Home Connection/Inquiry Science:* Ask students to observe the constellations or stars visible over the course of several weeks. They should look in the same direction at the same time each night and record their observations in a science journal. Ask them to note how the stars move over time. Then challenge students to explain why the stars seem to move and to make predictions about where the stars will appear in future weeks. Have students compare their predictions with new observations.
- *Writing:* Have students write stories about where the *Diver* ended up on the "other side" of the black hole. Or invite students to write another adventure in space for the characters in the story.
- *Reading/Writing:* Invite students to read folktales from various cultures about the creation of stars and constellations. Then challenge them to write their own tale about the origin of a star or constellation.
- *Arts:* Invite groups of students to create skits based on one of the *I.Files* they read. Students should include the characters from the *I.Files* as well as details about the featured stars.
- *Math/Arts:* Challenge students to create a scale model demonstrating different sizes of star types in relation to one another. Students may create a model based on diameter by creating a mural, a bulletin board, or outdoor art. Alternatively, they may wish to create a 3-D model using spherical objects or other art materials.
- *Math/Research:* Ask students to research what light-years are. Help them find the distance in light-years from Earth to the stars mentioned in the *I.Files*. Then challenge students to convert these distances to kilometers or miles.
- *Research/Technology:* Use the Internet to locate images of objects outside the solar system, such as those provided by NASA. Have students create a digital presentation based on the image, including what it shows and how scientists were able to capture it (e.g., with visible light, space telescopes, or X-ray or radio telescopes).