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# Session 6 – Stars and Their Lives

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## **Brief Description**

Students learn that our Sun is a star. They are then led through a kinesthetic modelling activity to learn how the life cycle of a star depends on its mass. The next session (Session 7) goes into more detail about how stars fuse elements in their core, and how those elements are dispersed into the Universe at the end of their lives. Session 7 is intended to be an optional extension of this session for those leaders who wish to get into a more detailed exploration of stars.

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## **Objectives**

- To ensure that students understand that our Sun is a star.
- To show how stars go through life cycles dependant on their masses.

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## **Concepts Addressed**

- The effect of distance on how bright a source of light appears
- Energy generation in stars
- Balance of forces in the interiors of stars

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## **Materials**

- A blackboard, whiteboard, or a flipchart on an easel
- Chalk or markers
- Two 8" × 11" sheets of cardboard or thick construction paper
- Two identical sources of light — an uncovered table lamp with a 10W or 20W frosted bulb is best
- *The Lives of Stars* handout (black and white version included in Appendix E and color version included in Appendix F)
- Images of stars at different stages in their life cycles (included in Appendix F)
- Pair of scissors

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## **Other Requirements**

- Large room with sufficient space for students to model the life cycle of a star
- A long dim hallway or a room that can be darkened
- Electrical outlet for lamp

## Background

Stars are big balls of hot gas, mostly hydrogen. Our Sun is a star, the closest one to Earth, and this is why it looks so big and bright. The Sun has a mass that is about 330,000 times more than the Earth. Its radius is about a 100 times that of the Earth, so a million Earths can fit inside the Sun! Our Sun is large relative to the planets, but it is an average size in comparison to other stars. In the extreme, stars can be up to 100 times more massive than the Sun.

Stars generate energy by converting lighter elements to heavier elements by a process of nuclear fusion in their cores. These elements act like the “fuel” to generate a star’s energy. This energy flows outward and counterbalances the inward gravitational force. Stars spend the majority of their lives with these two forces in balance, as shown in the image to the right.

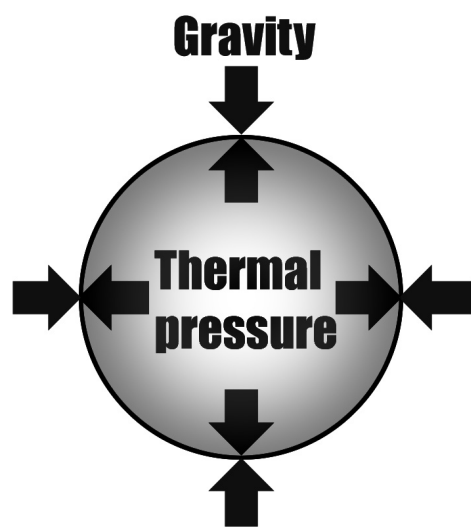
Stars go through a cycle of birth and death, but the timescales involved are much longer than we associate with living things (which stars are not). Young stars are born in clouds of gas and dust called a nebula. Particles inside these nebulae collide and clump together due to the force of gravity. When enough material has accumulated, fusion kicks in and a star is born!

The lifetime of a star depends on how massive it is. Small stars live many billions of years, but the most massive stars live only a few million years. Our Sun, a medium star, is 4.5 billion years old and about halfway through its life cycle.

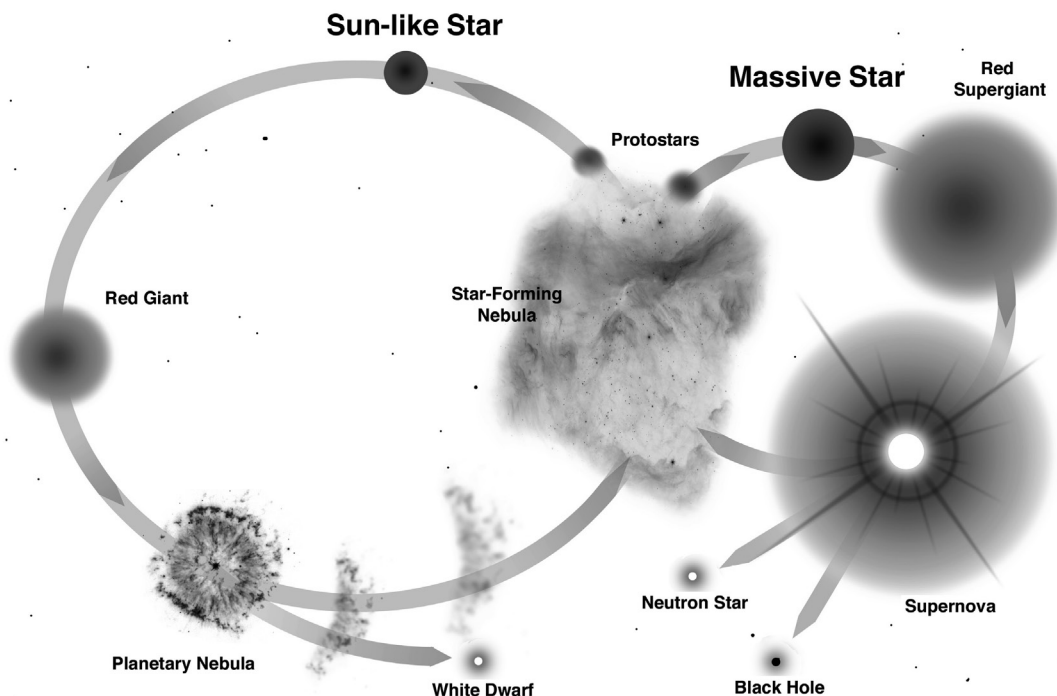
Stars that are not very massive (like our Sun) spend the majority of their lives (many billions of years) in a phase known as the “main sequence” stage in their lives. During this stage, they fuse hydrogen into helium in their cores. When this fusion ends, they expand into a “red giant” phase. Our Sun will become a red giant 5 billion years from now. At this stage in its life, the Sun will puff up and swallow the Earth. After a brief phase in which helium is fused into carbon, red giants blow off the outermost layers. These layers form a disk of material around the star – this is called a “planetary nebula” as it looked like a planet when seen through early telescopes. However, this has nothing to do with planets.

The hot core that is left behind is approximately the size of the Earth and is called a “white dwarf.” White dwarfs are very dense — a teaspoonful of white dwarf material would weigh 15 tons on Earth! White dwarfs shine for many more billions of years as they slowly cool.

The most massive stars run through their “fuel” at their centers in only a few million years. When the fuel is used up, the force of gravity overwhelms the outward push from the energy generated by the fusion. As a result, the core regions of the star collapse catastrophically releasing enough energy to blow apart the rest of the star. This is called a “supernova explosion.” These explosions are so bright that they briefly outshine entire galaxies! Supernovae (the plural of supernova) also have so much energy that elements heavier than iron are formed during these explosions. With the exception of hydrogen



*The balance of forces within a star.*



*The lifecycles of both a small to medium star and a massive star.*

and trace amounts of other small elements, all of the elements that make up our body (carbon, oxygen, nitrogen, iron, etc.) were formed either through nuclear fusion inside of stars or during supernova explosions. All the elements that were formed inside the stars are spewed out when they explode, and this is how elements are dispersed throughout the Universe. We are all literally made of star stuff!

From these more massive stars, the core left from the supernova may be a neutron star or a black hole. A neutron star is an extremely high density star, where gravity is so strong that protons and electrons combine to form neutrons. The density in the interior of a neutron star is much higher than in the interior of a white dwarf. A sugar-cube sized lump of neutron star material would weigh 100 million tons on Earth!

But, if the star is massive enough, the object left after the explosion is still too massive to support itself against gravity. The object continues to collapse until it forms a black hole. A black hole is a point in space with tremendous gravity — so great that not even light can escape from it, hence the term “black” hole.

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**Session Overview**

This session begins with an activity to help students recognize that the Sun is a star and looks bright only because it is so close. It is then followed by an activity where students act out the life cycle of a star and learn the different stages a star goes through from birth to death.

## Preparation

- Cut a 1" diameter hole in the centers of the two pieces of cardboard or construction paper.
- Print copies of the images of stars at different stages in their life cycle, cut apart, and laminate them or paste them onto cardboard or construction paper.
- Print copies of the *Lives of Stars* handout.
- Familiarize yourself with the *Lives of Stars* handout.

## Activity

### I. Our Sun is a Star (15 minutes)

This activity is intended to demonstrate how things look brighter when they are closer and fainter when they are far away. It is best done in a long dim corridor, if possible. But a regular classroom will also work.

1. Start by discussing whether students have seen car headlights on the road at night. Ask if they notice what happens when cars are near them and when they are far away. From this discussion, students should get the idea that the same headlights looked faint when they were far away and much brighter when they were closer.

*(You can use other examples that might better suit the experiences of your students. For example, street lights get bigger and brighter as you walk towards them and dimmer as you walk away from them.)*

2. Now, darken the room and have a volunteer stand at one end of the room with an uncovered lamp. Have them hold the cardboard or construction paper with the hole in front of the bulb so that only a circle of light is seen. This represents our Sun. Have another volunteer stand next to the first with the second lamp representing an identical star. Have the rest



*Students observe two identical bulbs at the same distance.*

of the students look at the two lamps. Ask them how bright the “Sun” looks from where they are standing. How bright does the other “star” look? Have them confirm that the two lamps are indeed identical, and they are the same brightness because they are both at the same distance. (Note: If the two bulbs are identical and sufficiently round, the cardboard or paper is unnecessary for this demonstration to work.)

- Next, have the volunteer with the “star” move a little further away while the volunteer with the “Sun” stays close. Ask the other students if the two lamps look the same now. Hopefully, they will be able to see that the “star” does not seem as bright as the “Sun,” even though we know that they are identical. Have the volunteer with the “star” move progressively further away from the “Sun” and repeat the conversation each time.

Finally, have the volunteer with the “star” move as far away from everyone as possible. This simulates our nearest star compared to our sun. Ask all the other students to cluster together at the opposite end of the room and ask how bright this “star” looks. With one lamp near, and one lamp farther away, do they still look the same in brightness? Make the point that this is the same lamp, so the brightness is the same as before (as our “Sun”). Next, ask if it might ever get to a point where it looks only like a little bright dot. The students should get the point that the “Sun” looks big and bright the closer we are to it.



*When the two bulbs are at different distances, they will appear to be different sizes and brightnesses, even though they are identical.*

(This comparison works best in spaces that are large enough for the distances to make a difference. If you are in a small space, you can try this activity with smaller/dimmer bulbs.)

- Now ask what would happen if we took one of these lamps outside into the sunshine. Would we be able to see the light from this bulb? It would be lost in the Sun’s glare! Similarly, the stars are always there in the sky, but we can only see them when it gets dark because the sunlight is too bright during the daytime. Ask if anyone has ever witnessed a total solar eclipse — the sky gets very dark during the daytime and we can see the stars!
- The students should now be led to the conclusion that the other stars in the sky are just like our Sun. They look so small because we are very far away from them. Remind them of the postcard activity in Session 3. If someone was to mail a postcard from the nearest star to us, it would take over 4 years to reach us if it traveled at the speed of light! Space is very big!
- Write the following on the blackboard/whiteboard/flipchart:

**Our Sun is a star, just like the tiny points of light we see in the sky at night. It looks bigger and brighter only because we are very close to it.**

## II. Stellar Life Cycles Kinesthetic Activity (~25 minutes)

*(Adapted from the “Kinesthetic Life Cycle of Stars” activity developed by Erika Reinfeld at the Harvard-Smithsonian Center for Astrophysics and Mark Hartman at the MIT Kavli Institute for Astrophysics and Space Research.)*

During this activity, students will model the life cycles of stars. Hand out the Lives of Stars handout and explain that during this exercise the students will take on the different roles shown in the cycle. They will act out the birth, life, and death of a star!

Clearly explain any and all safety considerations to students. Impress on the students that they must not hurt each other as they move about and act out the life of a star. You may want to conduct this activity outside, if space is limited.

Guide each section of the life cycle with specific steps – instead of having student rush inward and outward, instruct them to “take three steps backward” or another cue to proceed calmly to a new position.

The majority of physical contact between students should take place with only hands, but if this is an issue for you or your students, even this is unnecessary.

If you are comfortable with it, students can be encouraged to make sound effects where appropriate – explosions and collapses can be dramatic! The overall noise of the activity should be kept quiet enough to hear leader instructions throughout.

Before beginning the activity, write on the blackboard and verbally ask the following questions:

- *What holds a star together?* (Answer is gravity.)
- *Do stars change over their lifetime?* (Yes.)

Explain that this next activity will show how stars change and what might make them change. Tell them that they will play the roles of a star in the different stages of its lifetime. You will start with the life cycle of a small or medium-sized star, and then repeat the activity for a large star. It is recommended that you do a trial run of each activity, and then repeat it for maximum impact and understanding.

### SMALL & MEDIUM STARS

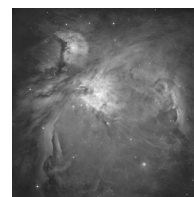


This kinesthetic activity models the life of a small to medium sized star, such as our Sun. Check our online resources for a video about the small star kinesthetic.

Each person involved in this activity represents a bit of the material that goes into making such a star.

- **Stage 1: Star Formation**

Students should move around or dance freely and be as spread out as possible to simulate that bits of space matter are hanging out more or less randomly as a cloud in space. If space allows, students should have their arms partially or totally stretched out at their sides.



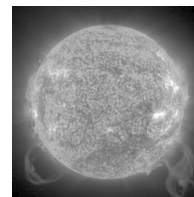
The activity facilitator should give the students a cue (such as a reminder that gravity will pull things together). After this cue, when students come close to each other, they should remain close, adding more and more students to the group until everybody is included in the big circle. There should remain plenty of space between the people at the center, so they have enough room to group further together as the activity progresses.



*Students dance freely in the star formation stage of the life cycle activity.*

- **Stage 2: Main Sequence Star**

Once all of the students are clumped together, we say that a star has been born. The students at the edges form a ring facing inward, as the outer shell of the star. They should raise their hands in front of them, palm outward, to represent the inwardly directed force of gravity. Those at the center – the core of the star – should face outward and put up their hands in front of them in the same way. This represents the energy generated by the fusion of hydrogen at the center of the star, which causes an outward pressure. The two groups are now effectively pushing at



*Students act out the main sequence star stage of the life cycle activity.*

each other, palm to palm, without moving. The students that form the shell may push gently inward, and the students that form the core may push gently outward with the same force. This represents the balance of forces that characterizes a star on the Main Sequence, where stars spend most of their life.

- **Stage 3: Red Giant**

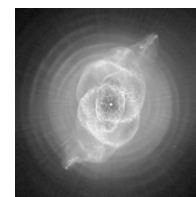
After billions of years, our star runs out of hydrogen (its fuel) to fuse at the center. When this happens, the students in the center stop pushing outward and drop their hands, symbolizing the loss of that outward pressure that comes from the fusion process. The students representing the core take a tiny step backwards, bringing them closer together, a result of the gravitational force without the balancing outward pressure. Because everything in the core is now closer together, it heats up, which gives our star enough energy to start fusing all that helium that has built up, and it has a new fuel! Not only do the students that represent the core put their hands back up, but because of all the extra heat, the outward force is even greater than before! To show this, the shell students take a step away from the core students. Point out that the star has now increased in size! This is what we call a Red Giant.



*Students act out the red giant star stage of the life cycle activity.*

- **Stage 4: White Dwarf**

Eventually the star runs out of helium to fuse at its center as well. Once again, the students in the center stop pushing outward and drop their hands, the gravitational force briefly overwhelms the star, and the students representing the core take another tiny step backwards. As before, this causes the core to heat up some more, but in a small star, it can't heat up enough to fuse any other elements. All the heat can do is give one last dying push of energy, pushing the shell away. The core students take another tiny step backwards, forming what we call a “white dwarf.” The shell students drift off, representing material dissipating into space. While this shell material is dissipating, we call this a planetary nebula. Point out the spot in the handout/poster they are now at.







*Students act out the white dwarf star stage of the life cycle activity.*

The students should understand this is the end of one star’s life, but the material that drifts off into space can go on to participate in other dances and create new stars.

## LARGE STARS

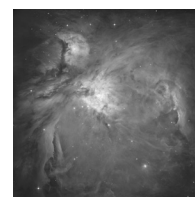


Check our online resources for a video about the large star kinesthetic.

This kinesthetic activity models the life of a large star that is many times the mass of our Sun. Each person involved in this activity represents a bit of the material that goes into making such a star.

- **Stage 1: Star Formation**

Students should move around or dance freely and be as spread out as possible to simulate that bits of space matter are hanging out more or less randomly as a cloud in space. If space allows, students should have their arms partially or totally stretched out at their sides.



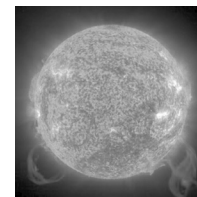
The activity facilitator should give the students a cue (such as a reminder that gravity will pull things together). After this cue, when students come close to each other, they should remain close, adding more and more students to the group until everybody is included in the big circle. There should remain plenty of space between the people at the center, so they have enough room to group further together as the activity progresses.



*Students dance freely in the star formation stage of the life cycle activity. This stage is the same for large stars as it is for small and medium stars.*

- **Stage 2: Main Sequence Star**

Once all of the students are clumped together, we say that a star has been born. The students at the edges form a ring facing inward, as the outer shell of the star. They should raise their hands in front of them, palm outward, to represent the inwardly directed force of gravity. Those at the center – the core of the star – should face outward and put up their hands in front of them in the same way. This represents the energy generated by the fusion of hydrogen at the center of the star, which causes an outward pressure. The two groups are now effectively pushing at each other, palm to palm, without moving. The students that form the shell may push gently inward, and the students that form the core may push gently outward with the same force. This represents the balance of forces that characterizes a star on the Main Sequence, where stars spend most of their life.



*The main sequence stage is also the same for large stars as it is for small and medium stars.*

- **Stage 3: Red Giant**

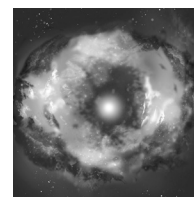
After billions of years, our star runs out of hydrogen (its fuel) to fuse at the center. When this happens, the students in the center stop pushing outward and drop their hands, symbolizing the loss of that outward pressure that comes from the fusion process. The students representing the core take a tiny step backwards, bringing them closer together, a result of the gravitational force without the balancing outward pressure. Because everything in the core is now closer together, it heats up, which gives our star enough energy to start fusing all that helium that has built up, and it has a new fuel! Not only do the students that represent the core put their hands back up, but because of all the extra heat, the outward force is even greater than before! To show this, the shell students take a step away from the core students. Point out that the star has now increased in size! This is what we call a Red Giant. Point out that we were at the same stage for the smaller stars – both small and large stars go through this stage (though the time-frames involved are different). However, what happens next is different for the two types of stars.



*Students once again act out the red giant stage of a star's life cycle.*

- **Stage 4: Supernova**

As with a smaller star, eventually the core runs out of helium to fuse. Once again, the students in the center stop pushing outward and drop their hand, the gravitational force briefly overwhelms the star, and the students representing the core take a tiny step backwards. As before, this causes the core to heat up some more, because everything is closer together. In a large star, this is sufficient to start the next level of fusion. The students that represent the core put their hands back up, and again the shell students take a step away from the core students to represent the greater outward force.



The largest stars are able to go through these steps multiple times, contracting the core and expanding the shell of the star outward with each repetition. The students can act this out multiple times, continuing to face each other and “push” with a balance of forces in between each collapse and expansion phase.

Eventually, the core of the star is made of iron, and at this point it has really run out of fuel! No matter how big the star is, it can't get enough energy to fuse iron. The outward force again goes away, and the core students stop pushing outward and drop their hands. Since the inward force of gravity is still in effect, but the core has no more energy to hold it up, the core collapses – the core students take another step backwards.



*Students acting out the part of the star's shell rebound off of the core and fly off into space to form other stars.*

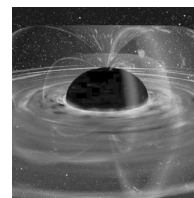
When the core collapses, two things happen simultaneously:

1. The core heats up dramatically, causing one last outward wave of energy and pressure. In our activity, the students who make up the core of our star should make a stronger push outward than any they have made so far.
2. With nothing to balance the gravitational force, the shell rushes inward towards the core. The students who make up the shell should rush inward towards the core, with their hands still raised.

When the shell material reaches the outward pressure wave, it rebounds off and explodes outward. Our students represent this meeting when the hands of the students in the shell meet the hands of the students in the core, which are pushing outwards. The shell students should bounce (gently) off the core students' hands and explode outward in all directions, simulating the supernova! (This is labeled as "Supernova" on the handout.)

The core students then take a final step backwards, ending up closer together than they have been up to this point, because the core collapses even more and creates an even denser object than a white dwarf: either a neutron star or a black hole, depending on the original mass of the star.

At this point, ask the students to tell you what this looks like. Ask them if they have ever been in this position before.

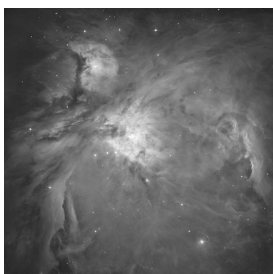


It is important to point out that from these points, the endpoints of each dance, the cycle starts again with Stage 1. Collect the group back together, and conduct a discussion about what they just did. Look at the handouts and/or poster and walk through the activity that was done. Ask students to describe what was going on at each stage.

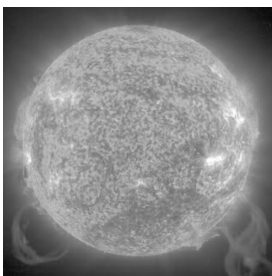
Now, revisit the questions that you asked originally. There should be a consensus as to the answers, and an understanding that stars go through stages that are part of a cycle.

### III. Matching images of stars to the handout (10-15 minutes)

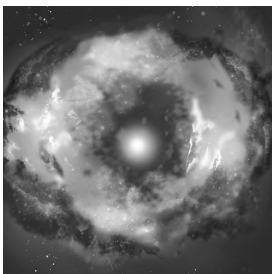
1. Split the students into groups of 2 or 4. Distribute the images of the stars at different stages in their life cycles to them. The images given are:



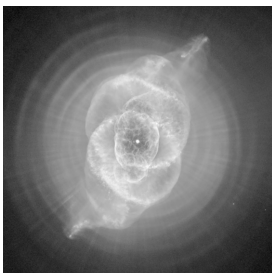
*The Orion nebula as an example of a gas cloud in which stars are born*



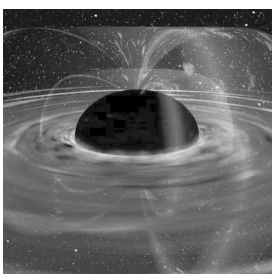
*An image of our Sun (taken by the SOHO spacecraft), as an example of a main sequence star*



*An artist's impression of a supernova explosion*



*A picture of a white dwarf (that, in this case, is surrounded by a “planetary nebula” which is the gaseous remains of the original star but has nothing to do with a planet)*



*An artist's impression of a black hole*

2. Talk about how these five objects are connected to each other and what is going on in each image. Now ask the student teams to cut apart the images. Ask the students to place the images on the handout at the proper stage in the cycle. Ask for students' thoughts.

Please note, some of these objects are from the life cycle of a low-mass star, and some are from the life cycle of a high-mass star, so don't let that confuse you.

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### ***Suggestions for Running this Session***

- Because this is an activity where everybody gets up and moves around, you may need to be conscious of crowd control issues. If this is an issue, have the students do all actions slowly and gently, and remind them that we are all peaceful, non-violent stars. In the end, you know your group best, so treat them accordingly.
- If you feel that physical contact is an issue for your group, it is entirely possible to do this session without any touching at all. Set up those ground rules at the start of the activity if that's the route you want to take.

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### ***Misconceptions***

- Before this session, many participants may have heard something about supernovae and carry the misconception that the Sun will end its life in a violent explosion or a black hole. This is untrue, as the Sun will follow the life cycle of a small/medium star, ending up as a white dwarf with a planetary nebula. Remind them of this during the activity, to emphasize which life cycle will apply to the Sun.

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### ***Useful websites for background or activity extension***

- ***Imagine the Universe!***  
Check out this site for more information and activity books on the life cycles of stars. Designed for educators at the high school level.  
<http://imagine.gsfc.nasa.gov/docs/teachers/lifecycles/stars.html>
- ***Chandra Science Center***  
This site offers a clear but higher level explanation of the story of stellar evolution with interactive graphics and animations. There are also suggestions for other activities and web-based games.  
[http://chandra.harvard.edu/edu/formal/stellar\\_ev/](http://chandra.harvard.edu/edu/formal/stellar_ev/)