Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2005 Volume IV: The Sun and Its Effects on Earth

Stellar Evolution and the Fate of Earth

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Introduction

Life on Earth would not have been possible were not for the process of star formation that has been continuously occurring since the Universe began to expand some 13-15 billion years ago. Each star evolves in a slightly different way depending on the initial mass of the star. Stars begin their life as a vast cloud of dust and gas (mostly hydrogen gas). Gravitational forces bring these particles and gases together until the conversion of gravitational potential energy to heat causes the temperature to raise enough to allow hydrogen fusion. Once hydrogen starts fusing into helium, a star is born.

While all stars form in the same way, the path a star takes to its eventual death is not always the same. How a star ends its life is dependent on its initial mass. Low mass stars (about five times the mass of the Sun or less) will evolve and end their life as a white dwarf. Intermediate mass stars (five to ten times the mass of the Sun) will evolve and end their life as a neutron star while the most massive stars become black holes.

Life on Earth owes its existence to the process of stellar evolution, for without it our sun would never have been created and therefore never have been able to bathe out planet with its life giving energy. It should be noted, though, that it is this same process of star formation and death that will some day be the demise of the Earth and all life on it. Current measurements suggest that the Sun is halfway through its ten billion year life cycle. It has continuously increased its heat energy output over the past 5 billion years and will continue to for the next 5 billion years.

In addition to addressing the concerns and questions that my eight-grade students have about stars, how they form, how they die, and what that means for life here on Earth; the development of this curriculum unit will also be guided by the New Haven Public School scientific inquiry performance standards that state that students will identify questions that can be answered through scientific investigations, that students will develop descriptions, explanations, predictions and models using evidence, and that students will recognize and analyze alternative explanations and predictions about the world around them. Also aligned with the unit are New Haven's Earth Science performance standards, which state that students will describe the features of our sun and how it compares with other suns in the universe and that students will describe other effects of the sun's energy on our world such as weather and winds, the growth of plants, and the water cycle. Using these standards as a guide, I will focus on, and develop the following topics related to stellar evolution for the classroom: 1) The sequence of events as stars form, "burn" their fuel, and then end their life, and 2) The fate of our Earth as our own sun progresses through its evolution.

The first lessons in the unit will be themed around the life cycle of stars. Stellar life cycles are determined mainly by how much mass the star initially has. A high-mass star will eventually become either a neutron star or a black hole, while a low and intermediate mass star will end its life as a white dwarf. I will use a hands-on strategy to teach this topic. One activity will involve the students choosing a known star and then illustrating its life cycle based on what its initial mass was. The students will be responsible for describing each stage as well as illustrating it on paper. In addition, they will determine if their star's evolution would change if it started with one half, and twice, its true initial mass.

The second area of focus will be on Earth and how the sun's evolution will affect it. Again my strategies for teaching will include hands-on activities such as creating models of the sun in various stages of its evolution. However, there will be more of a focus on mathematics and determining how much material the sun is burning and how long the sun will continue to do this. In building on previous knowledge and skills, the students will once again determine how our sun's fate changes if it had started with one half, and twice, its true initial mass. As the students grasp the processes of stellar evolution, we will look at how Earth is affected by this process. The students will answer the central question of how does the sun's fate effect the Earth's fate. The students will construct a timetable that will show the interactions of the sun and Earth as the sun evolves.

Objectives

The students will be able to describe the role gravity plays in stellar evolution.

The students will be able to describe the composition of a star and how it relates to the process of stellar evolution.

The students will be able to determine how a star will evolve based on its initial mass.

The students will be able to read and interpret the Hertszsprung and Russell Diagram.

The students will be able to describe the variety of stars based on size, temperature, and mass.

The students will be able to describe how our sun has evolved and how it will continue to evolve.

The students will be able to describe how life on Earth will be affected as the sun evolves.

Background Information

Birth of a Star

The birth of a star begins with a huge mass of dust and gas known as a giant molecular cloud, or nebula. Giant molecular clouds are so massive that as much as a million stars can form from them.1 In our own galaxy alone there are thousands of such giant molecular clouds. Despite how massive these clouds are though, they are not very dense because they are spread out over vast distancesup to 200 light years in diameter. However, relative to the interstellar medium, these giant molecular clouds are considered very dense and can be more than a thousand times denser. To give perspective, Earth's atmosphere is about a trillion time more dense that a giant molecular cloud.18

These massive clouds of dust and gas are not uniform in density. As a result, in the areas that have more density, gravity begins to pull together more and more particles and gases. In the most massive of Giant molecular clouds, gravity can independently pull together the massive amount of material. However, in smaller clouds or fragments of giant molecular clouds where there is only ten to hundreds of solar masses worth of material it is not uncommon that a shock wave from a nearby exploding star or the passage of these clouds through an area of higher gravity be required for condensation of the material to occur.17

As these areas become more massive, gravity becomes stronger and pulls even more material together. Gravity eventually causes areas within the giant molecular cloud to collapse. As collapse occurs, gravitational energy is released and the gas becomes very hot. As the cloud collapses internal pressure from all the gas molecules begins to push outward. It is this battle between the inward pull of gravity and the outward push of internal pressure that characterizes the stars fight for life and eventual forfeit to death.2 As this battle is occurring, the material is not yet a star. This point when the material is contracting and heating up that it is called a protostar.

Protostars are not yet stars because they have not reached internal temperatures high enough to begin nuclear fusion. As the cloud of gas and dust contract because gravitational forces are more powerful than the internal pressure forces, the temperature of the cloud increases. It is not until the protostar reaches a temperature of 10,000,000 Kelvin that its hydrogen gas fuses to form helium.3 It is at this point that a true star has formed. As the star fuses its hydrogen into helium, the internal pressure increases and begins to balance the inward force of gravity and the star becomes stable. It is at this point that the star is said to be a main sequence star.4 Before continuing with a discussion of the various stages of stellar evolution, it is important to discuss the Hertzsprung-Russell diagram.

The Hertzsprung-Russell diagram

In two independent studies early in the twentieth century Danish astronomer Ejnar Hertzsprung and American astronomer Henry Norris Russell focused their attention on two characteristics of a starits luminosity and its temperature. Hertzsprung and Russell plotted the luminosities and temperatures of stars on a graph in which the luminosity increases upwards on the "Y" axis and the temperature decreases toward the left on the "X" axis. Both astronomers came to the same discovery that a star's luminosity is related to its temperature. In most cases, the relationship follows that as the stars luminosity increases its temperature also increases.

For most stars this relationship between temperature and luminosity holds true. These stars, when plotted on the H-R diagram, create a line of stars that go from the bottom left (cool and not very luminous) to the upper right (hot and very luminous). Those stars that follow this relationship and are thus plotted in this general line on the H-R diagram are known as main sequence stars. However, not all stars follow this pattern or relationship that the more luminous the star the hotter it is. Looking at the H-R diagram, one notices that some stars fall outside the main sequence belt. For example there is a group of stars which when plotted fall above and to the right of the main sequence. For these stars, their luminosity is high but their temperature is low. These stars are known as red giants and supergiants. In addition, there is an area on the H-R diagram in which stars lie below and to the left of the main sequence. These stars have low luminosities but very high temperatures. Such stars are known as white dwarfs.

Why is this important? Well stellar evolution can be described by how a star's luminosity and temperature change over time.5 These changes are a result of the competition between the inward force of gravitational contraction and the outward force of pressure. As a star fuses its hydrogen into helium, both its temperature and luminosity change. Therefore, scientists can use the Hertzsprung-Russell diagram and a stars position on it to describe its current evolutionary stage. All stars begin as main sequence stars and are first plotted allow the main sequence line since their luminosity is in relationship with their temperature. Stars will spend about 90 percent of their life in the main sequence stage, which explains why about 90 percent of the known stars are plotted in this area.19 It is convenient, therefore, to discuss the evolution of stars with respect to where they lie on the H-R diagram.

When a star becomes a main sequence star, nuclear fusion has begun and it has become a stable star. A main sequence star's position on the H-R diagram is dependent on the star's initial mass. A Star with high mass will have a higher luminosity and higher temperature. A low mass star therefore will be plotted with a lower luminosity and temperature. The initial mass also determines how long a star remains as a main sequence star. High mass stars fuse their hydrogen much faster than low mass star.6 Therefore, a high mass star will become unstable quickly and move onto the next stage in a stars life cycle whereas low mass stars will burn the fuel more slowly and remain as a main sequence star for a longer period.

Main Sequence Stars

A main sequence star fuses its hydrogen into helium and spends most of its life in this stage. The amount of time spent as a main sequence star is dependent on how fast the star fuses its hydrogen. The speed at which a star fuses its hydrogen is, in turn, dependent on how much mass the star has. More massive stars have a stronger gravitational attraction force and therefore higher temperature are required to provide the pressure to counteract gravity. The higher temperatures allows more fusion, which leads to a shorter time as a main sequence star.7 The opposite is true for low mass stars. The most massive of stars only spend a few million years as main sequence stars while low mass stars may remain for 10's of billion years. Our sun will remain as a main sequence star for another five billion years. It is currently about five billion years oldhalf way through its life cycle. Up until now, all stars follow the same steps in the life cycle to become a main sequence star. However, now a star's mass will determine whether it will become a white dwarf, neutron star, or a black hole.

Becoming a Red Giant

The next stage in the life of a star occurs when all the hydrogen in the core is fused into helium. Since energy and heat are no longer being produce by the fusion of hydrogen, the core cools and begins to contract. Helium, which now makes up the core requires much higher temperatures to fuse and therefore does not begin to fuse until gravitational force cause the core to collapse and heat up to even higher temperatures. Before that happens though, the outer hydrogen shell that now exists around the helium core increases in temperature due to the contracting helium core that is heating up and producing enough heat to allow the hydrogen shell to fuse its hydrogen that is nearest to the core. The heat produced from this fusion moves outward and causes more hydrogen farther out in the hydrogen shell to fuse. This causes the outer shell to expand, which in turn causes its temperature to decrease. The expanding shell causes the luminosity of the star to increase. Thus the stars position on the H-R diagram changes as it temperature decreases and its luminosity increases. The now larger, cooler outer shell takes on a reddish color and the star is now called red giant.8

The next step in the evolution of a red giant is when the helium core that has been contracting gains enough energy to begin fusion. When the core heats up to 100 million K the helium begins to fuse. The heat generated from this process causes the surface temperature of the star to increasethus changing its position on the H-R diagram again. During this process, the stars plot moves to the left on the H-R diagram.

As the helium is used up in the core, the process repeats itself with oxygen and carbon fusion in the core after contraction has risen the temperature again. The outer shell that is now helium that fused from hydrogen is heated, expands, cools and turns red again. The hydrogen and helium shell begins to drift off into space and creates a huge shell around the carbon/oxygen core. This shell is known as a Planetary Nebula.9

Final Stage for Intermediate Mass Stars (5-10 times the mass of the Sun)

As the hydrogen and helium shell drifts off into space, the core continues to contract but there is not enough heat generated to cause the carbon/oxygen core to fuse into other elements. Therefore, the core simply contracts until it become very dense and the gravitational forces balance the internal pressure forces generated when the electrons are squeezed together by gravity. At this point it becomes a white dwarf.10

White Dwarf

As stated above, a white dwarf stars forms when the gravitational force balances the internal pressure force in the core. This occurs when the electrons are squeezed together so tightly that they can no longer be squeezed together and therefore the core cannot contract any further. If further contraction were to occur it would break a fundamental rule that govern how electrons behave, which is that no two electrons can occupy the same space at the same time doing the same thing.22 When the core becomes so dense that further contractions is prohibited, that gas is said to be degenerate. White dwarfs are stars with degenerate electron cores.

Since white dwarf stars can no longer contract, energy is no longer being produced in the core. Therefore, eventually the star will dissipate all of its heat energy and will stop glowing brightly. The star will become dimmer and dimmer until it no longer shines at all. It will be a cold stellar object.

A white dwarf star is so dense that one with a mass the same as the Sun will have a radius the same as Earth. It should be noted that the larger the mass of the star the smaller its final radius will be.23 The material in a white dwarf is so dense that a teaspoonful would weigh more than a garbage truck here on Earth.24

An Indian-American astrophysicist, S. Chandrasekhar, made the discovery that a white dwarf shrinks as the mass in the star increases. Chandrasekhar calculated that a white dwarf with a mass of about 1.4 solar masses (Msun) or larger would have a radius of zero.25 That means that not even the pressure from the degenerate electrons would stop the core from contracting further if the star's mass is higher than 1.4 Msun. Therefore, the maximum mass that a star can have and still become a white dwarf in known as the Chandrasekhar limit. Stars that have masses beyond this limit will further evolve and end their life in a different manner.

Final Stages of High Mass Stars (10 to 150 times the mass of the Sun)

In the case of a star that is 10 to 15 times the mass of the Sun, the core continue to collapse and is able to reach temperatures that allow the carbon/oxygen core to fuse into new, heavier elements. The cycle of core fusion, expansion, contraction and fusion again continues in high mass stars until the core in made of iron. Silicon, which fuses to iron, is the last fusion process that releases energy and allows the star to stay stable and balanced. As a result, the star's core continues to collapse without fusion taking place. The result is a core made of degenerate neutrons. Such a star is known as a neutron star. It has been found that if a high mass collapsing star's core is three time the mass of the Sun or less it will stabilize as a ball of degenerate neutrons. The result is called a neutron star.11

Neutron Star

The neutron star begins where the white dwarf left off. Again, if the mass of the star is more than 1.4 solar masses than the core will continue to contract. As the core become very dense and gravity squeezes the degenerate electron together more and more, some of the electrons are squeezed into the atomic nuclei. As the electrons are squeezed into the atomic nuclei they combine with the protons to form neutrons. As more and more electrons combine with protons to form neutrons, the pressure pushing out against the gravitational force become less and further contraction of the core ensues. Further contraction forces more of the protons in the atomic nuclei to combine with the electrons to the point that the atomic nuclei are saturated with neutrons and can no longer hold on to them.

What results as the neutrons are squeezed out and forced together is a degenerate gas of neutron much like the degenerate gas of electron that formed the white dwarf. Like the electrons the neutron resist being squeezed together and will reach a stable state in which no more contraction of the core will occur. Calculations have shown that a star with 3 solar masses will reach a stable state and remain a degenerate core a neutrons.25

If the mass of the star exceeds the above mentioned limit, its core of neutrons becomes unstable and continues to collapse and becomes and very dense object from which light cannot escape. This object is known as a black hole.12

The Sun's Evolution and the Fate of Life on Earth

To better understand how Earth will be affected by the evolution of the sun it is important to first describe the relationship between the sun, Earth, and life. For this Unit I will briefly describe, or outline, this relationship. Ideally, the subject of Life's relationship with the natural resources on Earth and those relationships with Earth's natural cycles and process would be covered in earlier units. Here we really want to focus on how the Sun affects Earth's natural resources such as water, gases, and soils. Life on Earth owes its existence to liquid water and the proper amounts of certain gases such as carbon dioxide, nitrogen, and oxygen to name a few.

In the past, the Earth had much more carbon dioxide. This is important because carbon dioxide allows solar radiation to pass through it but does not allow radiant heat from the Earth's surface to pass through. Instead it absorbs this heat and reradiated most of it back to the Earth surface. This process has come to be known as the greenhouse effect. This is an important process for life, for without carbon dioxide (and a few other greenhouse gases like methane and water vapor) the temperature of Earth's atmosphere at sea level would be 15 degrees Celsius (60 degrees Fahrenheit) colder.21 That is not to say that life is better off with increasing levels of carbon dioxide. If there is too much carbon dioxide then the Earth's temperature will rise too high and life will be threatened. It should be noted though that the Earth started with more carbon dioxide in its atmosphere than it currently has now. However, the sun's energy output was about 30 percent less and therefore in balance enough to create an environment that was not too cold or too hot for life to take hold. Overtime as the sun's energy output has increased the amount of carbon dioxide in the atmosphere has decreased well. That is, except for the past 50 to 80 years as the industrial revolution took hold. Increased use of fossil fuels and the cutting of forest have caused the Earth's carbon dioxide levels to increase. With the increase in carbon dioxide and other greenhouse gases, it is uncertain what will happen as the sun produces more energy and bathes Earth in ever increasing amounts of radiation. What is certain though is that no matter what our atmosphere is made of, eventually, the sun's will evolve through stages of life and eventually the energy it produces will be too great and will disrupt the delicate relationship between the sun's energy, Earth's natural resources and process, and all living organisms.

With a mass of 1.989 X 1030 kg, our sun is classified as a low mass star.13 And like all stars it began as a huge giant cloud of dust and gas. Gravity pulled these materials closer and closer together until the intense heat at the center cause the hydrogen to fuse into helium thus forming a protostar. Like all other stars on the main sequence, our sun has continuously increased the amount of heat energy being given off. That is to say that in the past our sun did not bath Earth in as much solar energy as it does today. In fact, it currently gives off 30 percent more heat energy than it did at its birth.20

Currently the sun is a main sequence star. It has been burning it hydrogen core for about 5 billion years and is expected to continue as a main sequence star and fully burn up the hydrogen in its core in about another 5 billion years.14 Relatively soon after all the hydrogen in the core is burned the sun will become a red giant as the outer hydrogen shell expands. This outer shell will expand to a size greater than that of the orbit of Mars, which is about 430 times larger than its current size.15

As the outer shell expands, the sun's luminosity will increase to about 20,000 times its current value. However, the surface temperature will lower to about 3,500 K while the core temperature reaches 100 million K.16 Earth will be bathed in more solar radiation and energy as the outer shell expands and nears Earth, thus casing the surface temperature of Earth to raise. It will continue to heat Earth until it is too dry and to hot for life to exist. Eventually, the burning hydrogen shell will envelope the Earth as well as Mercury, Venus, and Mars.

Strategies

Prior to starting the lessons on stellar evolution the students will be assigned homework involving readings from the textbook and from any current articles available at the time. I will begin the lessons on stellar evolution with an open discussion to answer any of their questions from the readings and to provide a basic overview of stellar evolution. After the discussion, the students will forms groups and each group will be responsible to describing how a specific star will evolve. This activity will continue for a second class period. At the end of which, the students will present their information.

The second lesson will involve science process skills such as classifying, making a data table and graphing. As homework from the previous lesson, the students will read about the H-R diagram and be asked to review star characteristics from an earlier unit. The lesson will begin with a discussion of the homework and an introduction to the H-R diagram. The students will given the names of two stars and also be asked to choose two stars from the appendix in their textbook and create data tables that show each start's characteristic such as luminosity, temperature, color, and current point of evolution (main sequence, red giant, white dwarf, etc.). The students will then use this data to plot the star on the H-R diagram.

The third lesson will involve the students determining the mass of the sun and its age and position on the H-R diagram. They will then be asked to describe how the sun will evolve from its current condition, and more importantly, how this will affect life on Earth. This lesson will focus more on mathematics and determining how much material the sun is burning and how long the sun will continue to do this. As the students grasp the processes of stellar evolution, we will look at how Earth is affected by this process. The students will answer the central question of how does the sun's evolution affect life on Earth. As a final activity, the students will write a letter to NASA stating what they have learned about stellar evolution and how the sun will affect life on Earth as it evolves.

Classroom Activities/Lessons

1st Lesson Plan

Stellar Evolution Day 1

Learning Objectives (At the end of this lesson my students will...)

Be able to explain how stars are formed.

Be able to describe the life cycles of medium-sized and massive stars and discuss current scientific ideas about black holes.

Materials

Homework Assignment: Readings and H-R diagram example

Poster paper

Markers/Crayons

Textbook

Star charts

Learning Activities

Prior to starting the lessons on stellar evolution the students will be assigned homework involving readings from the textbook and from any current articles available at the time. Begin the lessons on stellar evolution with an open discussion to answer any of their questions from the readings, and provide a basic overview of stellar evolution and how mass determines a star's evolutionary track. Use questioning to assess their understanding of the topic.

Continue the lesson with a group activity. Assign the students to groups that match up lower performing students with higher performing students. This will facilitate complete classroom learning. Create 5 to 6 groups of no more than four students per group. Give each group the name of a star and have the students use their textbook to look up the mass of that star. (Note: make sure that you provide different groups with stars of different masses. The goal is to show how a star's mass determines how it will evolve.)

Have the students determine the mass and then determine how the star will evolve based on the current information. For example if it is a low mass star, the students should find that the star would evolve from a main sequence to a red giant and then to a white dwarf. However, the groups that are given an intermediate or high mass star should show that the star would take a different evolutionary track.

Each group will be responsible for determining the evolutionary track of their star, writing a short essay describing the different stages, illustrating each stage, and finally presenting this information to the class. The presentations will take place during the second class period.

Lesson Closure (Assess their understanding)

Questioning

Homework: The Evolution of StarsInterpreting a Diagram

Reflection Time

2nd Lesson Plan

Star Evolution Day 2

Learning Objectives (At the end of this lesson my students will…)

Be able to define and describe the Hertzsprung-Russell diagram.

Be able to plot a star on the H-R diagram.

Be able to determine a star's temperature, color, luminosity, and current stage of evolution from reading a H-R diagram.

Be able to make a data table and graph such data.

Materials

Graphing paper

Ruler

Copies of H-R diagrams (without stars plotted on it)

Learning Activities

The second lesson will involve science process skills such as classifying, making a data table, and graphing. As homework from the previous lesson, the students will read about the H-R diagram and be asked to review star characteristics from an earlier unit.

Start the lesson with a discussion of the homework and an introduction to the H-R diagram. Discuss luminosity, temperature, and color. Show the students how color and temperature are related. Using an overhead projector, demonstrate how knowing a stars temperature and luminosity, one can plot it position on the H-R diagram. And from plotting the star one can determine the star's current point in its evolution. Once it is determined that the student understand the H-R diagram and how to plot a star on such a graph, give the students the names of two stars and also have them choose two stars from the appendix in their textbook.

Next have each student work independently to create data tables showing the star's name, mass, temperature, color, luminosity, and current point of evolution (main sequence, red giant, white dwarf, etc.). The students will then use this data to plot the star on the H-R diagram. End the class with a review of the sun's characteristics and location on the H-R diagram. Get the students to start thinking about how the sun will evolve. This will help lead into the next lesson that deals with the fate of life on Earth as the sun completes its evolution.

Lesson Closure (Assess their understanding)

Questioning to assess understanding and do a quick review of the sun's characteristics and location on the H-R diagram. Get the students to start thinking about how the sun will evolve. This will help lead into the next lesson that deals with the fate of life on Earth as the sun completes its evolution.

Reflection Time

3rd Lesson Plan

The Sun's Evolution and the Fate of Earth

Learning Objectives (At the end of this lesson my students will…)

Be able to describe the sun's characteristics such as temperature, color, and luminosity.

Be able to describe how the sun will evolve based on its initial mass.

Be able to describe how such an evolution will affect life on Earth.

Be able to write a informative letter about the fate of life on Earth as the sun evolves.

Materials

Poster Paper

Markers/crayons

Learning Activities

The third lesson will involve the students determining the mass of the sun, its age, and its position on the H-R diagram. Have the students locate the sun on the H-R diagram and determine the current luminosity, color, and temperature. Also have them note that the sun is located along the main sequence section of the graph. On an overhead projector, make a data table that shows the aforementioned characteristics as well as the sun's mass.

Start a discussion to review how a stars mass determines it's evolutionary path. Discuss with the class the age of the sun and how much longer it will continue to burn its fuel. Continue the discussion to determine as a class how the sun will evolve. Remind the students that they will be writing a letter to inform others of the fate of life on Earth. It is a good idea to have a student draw the stages on the board as the class discusses each stage. For example, every star begins as a giant molecule cloud, so have the student draw that stage first. Then have the student draw the protosun stage.

As the student begins to draw the main sequence stage, inform him/her that you want them to draw in the planets. Have the students explain what happens during the red giant stage. You can provide them with the figures for the distance that the outer hydrogen shell will expand to. They should be able to make the connection that the distance is close to the distance between the sun and Earth. Also discuss how the luminosity increases and the amount of radiation increases. Finally, relate the increase in the radiation and luminosity to the fate of life on Earth. Have the student write a letter describing these affects and how long it will take before this happens.

Lesson Closure (Assess their understanding)

Questioning to assess understanding.

Reflection Time

Resources

Reading for Teachers

Feather Ralph M., PhD, Susan Leach Snyder, Dinah Zike. National Geographic, Mc Graw Hill, N. Y., New York, 2004.

Fraknoi, Andrew, David Morrison, and Sidney Wolff, Voyages Though The Universe, Saunders College Publishing, N.Y., New York, 2000.

Murphree, Tom and Mary K. Miller. Watching Weather: A Low Pressure Book about High Pressure Systems and Other Weather Phenomena. Henry Holt and Company, N. Y., New York, 1998.

http://www.astronomynotes.com/index.html

http://www.astronomynotes.com/evolutn/s3.htm#A1.2.1

http://archive.ncsa.uiuc.edu/Cyberia/Bima/GMC.html

http://www.answers.com/topic/dark-nebula

http://www.astronomynotes.com/evolutn/s3.htm#A1.2.2

http://abyss.uoregon.edu/~js/ast122/lectures/lec11.html

http://abyss.uoregon.edu/~js/ast122/lectures/lec17.html

http://abyss.uoregon.edu/~js/ast122/lectures/lec19.html

http://imagine.gsfc.nasa.gov/docs/science/know_l1/dwarfs.html

http://www.astronomynotes.com/evolutn/s11.htm

http://www.astronomynotes.com/evolutn/s12.htm

http://search1.discovery.com/search?site=schContent&proxystylesheet=sch&num=10&client=sch&output=xml_no_dtd&getfields=*&filter=0&q=astronomy

http://school.discovery.com/ontv/videoclips/astronomy1.html

http://school.discovery.com/schooladventures/universe/

http://news.nationalgeographic.com/news/2003/04/0421_030421_deathofplanet_2.html

http://calspace.ucsd.edu/virtualmuseum/climatechange1/02_1.shtml

Reading for Students

Discover Channel, Night Sky: An Explore Your World Handbook, Discover Books, New York, 1999

Feather Ralph M., PhD, Susan Leach Snyder, Dinah Zike. National Geographic, Mc Graw Hill, N. Y., New York, 2004.

Murphree, Tom and Mary K. Miller. Watching Weather: A Low Pressure Book about High Pressure Systems and Other Weather Phenomena. Henry Holt and Company, N. Y., New York, 1998.

http://school.discovery.com/ontv/videoclips/astronomy1.html

http://school.discovery.com/schooladventures/universe/

http://news.nationalgeographic.com/news/2003/04/0421_030421_deathofplanet_2.html

http://news.nationalgeographic.com/news/2005/04/0406_050406_blackholes.html

http://news.nationalgeographic.com/news/2005/05/0524_050524_blackholes.html

http://news.nationalgeographic.com/news/2003/06/0619_030619_darkside.html

http://pulseplanet.nationalgeographic.com/ax/archives/01_sciencetemplate.cfm?programnumber=2506

http://calspace.ucsd.edu/virtualmuseum/climatechange1/02_1.shtml

Materials for Classroom Use

Poster paper or construction paper

Markers, colored pencils or crayons

Textbook and related articles (See above for a list of readings for students)

Star chart

Graphing paper

Ruler

Copies of H-R diagrams (without stars plotted on it)

Notes

1 Voyages Though The Universe, Fraknoi, Andrew, David Morrison, and Sidney Wolff, Saunders College Publishing, N.Y., New York, pp. 416

2 Ibid, p. 416

3 National Geographic: Earth Science, Ralph M. Feather Jr., PhD, Susan Leach Snyder, and Dinah Zike, Mc Graw Hill, N.Y., New York, pp. 737

4 Ibid, p. 737

5 Voyages Though The Universe, Fraknoi, Andrew, David Morrison, and Sidney Wolff, Saunders College Publishing, N.Y., New York., pp. 422

6 Ibid, p. 424

7 Ibid, p. 438

8 Ibid, p. 440

9 Ibid, p. 448

10 Ibid, p. 460

11 Ibid, p. 463

12 Ibid, p. 464

13 Ibid, p. 440

14 Ibid, p. 440

15 Website http://www.earth.uni.edu/~morgan/astro/course/Notes/section2/new8.html

16 Website http://www.earth.uni.edu/~morgan/astro/course/Notes/section2/new8.html

17 Website http://www.astronomynotes.com/evolutn/s3.htm#A1.2.1

18 Website http://archive.ncsa.uiuc.edu/Cyberia/Bima/GMC.html

19 Voyages Though The Universe, Fraknoi, Andrew, David Morrison, and Sidney Wolff, Saunders College Publishing, N.Y., New York., pp. 370

20 http://news.nationalgeographic.com/news/2003/04/0421_030421_deathofplanet_2.html

21 Website http://calspace.ucsd.edu/virtualmuseum/climatechange1/02_1.shtml

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