Name: ____________________ Teacher: _______________ Pd. ___ Date: ________

STAAR Science Tutorial 34
TEK 8.8A: Stars, Galaxies and the Universe

TEK 8.8A: Describe components of the universe, including stars, nebulae, and galaxies, and use models such as the Herztsprung-Russell diagram for classification.

Big Bang Theory of Universe Creation

- Scientists believe that the universe as we know it was created about 13.7 billion years ago in an event popularly known as the "big bang." According to the big bang theory, all of the energy and matter of the universe was once packed into a single point of space called the singularity. When this singularity exploded, the outward expansion of the universe began, a process that continues today. The first matter to condense out of this cooling, expanding universe were sub-atomic particles. As the expansion continued, hydrogen atoms were able to form. Clouds of these atoms (nebula) began to be pulled together into stars about a billion years after the big bang. Large groups of these first stars formed the first galaxies. See *Tutorial 36: Electromagnetic Waves* for a discussion of the evidence supporting the big bang theory.

Universe Components

- The **universe** contains all of the matter and energy known by humans to exist. Some scientists have hypothesized that there may be parallel universes that we cannot detect, but there is no evidence to support their existence. The universe is known to contain billions of galaxies, though it is impossible to actually count the number.
- A **galaxy** is a very large group of stars held together by gravity. It may contain as few as a 100,000 stars, or as many as several trillion stars. Our Sun is one star in our **Milky Way Galaxy**, which may contain about 200 to 400 billion stars and measure about 100,000 light years in diameter. (A light year is the distance that light travels in one year, about 9.5 trillion kilometers.) While we have never seen our own Milky Way Galaxy from the outside, we do look out to the rest of the universe from a point about 26,000 light years from its center. On a dark, clear night away from city lights, the dense band of stars crossing the sky, which to the ancients looked like spilled milk, are the stars of the Milky Way Galaxy.
- Galaxies are usually grouped into **galaxy clusters**. Our own "local group of galaxies" contains about 30 galaxies which are gravitationally locked in an inward-moving spiral. The largest of these galaxies is the Andromeda Galaxy, a spiral galaxy located about 2.5 million light years from Earth, which may contain as many as one trillion stars.
- The three main types of galaxies are spiral, elliptical and irregular galaxies, each named from its general shape.

- **Spiral galaxies** have "arms" of stars that spiral outward from the center. The overall shape is round and flat like a plate, but the dense center of a spiral galaxy is spherical. Younger stars are more likely found in the arms of the spiral, and older stars are most likely found in the center sphere. Scientists believe that the center of all spiral galaxies contains a massive **black hole**, an extremely dense area from which light cannot escape. Our galaxy is believed to be a barred spiral galaxy, similar in appearance to the Andromeda Galaxy.
- **Elliptical galaxies** are spherical or elliptical (oval) in shape. They may be older than spiral galaxies, because they do not seem to have as many nebulae and dust clouds, and thus cannot form as many new stars.
- **Irregular galaxies** are so named because they do not have a regular or defined shape. They may be the result of merged galaxies still being reorganized by gravitational forces.

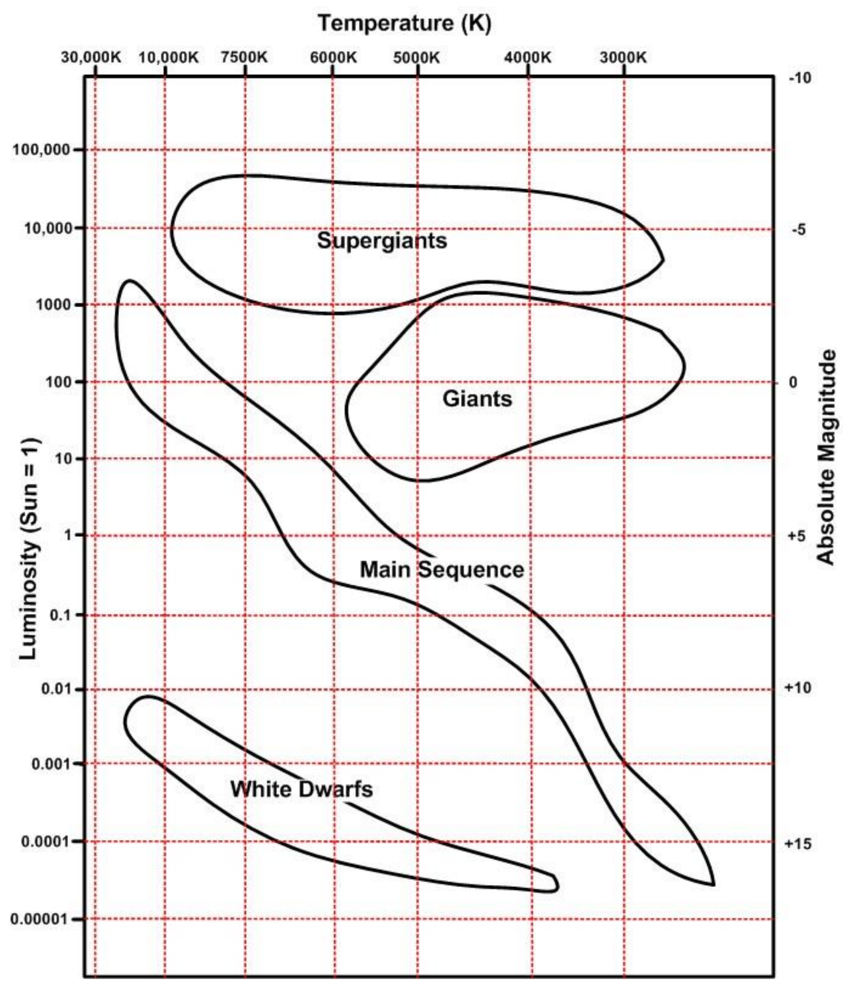
- Within the galaxies are **star clusters** containing between 10,000 and a million stars, held together by gravity. Most star clusters were likely formed at about the same time from the same nebula. Globular clusters are more tightly packed, and may contain older stars. Open clusters are more loosely packed and may contain younger stars.
- A **star** is a single, dense mass of matter that is hot enough at its core to support nuclear fusion. Stars vary greatly in size, temperature and color, as further discussed in the next section on the Hertzsprung-Russell Diagram. Most stars are found in pairs (binary stars) or small multiple-star groups. Our own star, the Sun, is unusual in that it is not part of such a group. For a detailed description of our star the Sun, see *Tutorial 35: The Sun*.
- **Nebulae** are diffuse clouds of gas and dust loosely held together by gravity. Scientists believe that new stars form in nebulae when compression waves from nearby supernova begin a consolidation and star formation process known as the Nebular Hypothesis. Diffuse nebulae may be the remnants of supernova explosions, the end of life of very large stars.
- **Planetary nebulae** are shaped like a sphere, ring or disc. They are believed to be the remnants of smaller stars like our Sun that explode outward at the end of their lives.

Hertzsprung – Russell Diagram

- During the late 1800s and early 1900s, many scientists were using telescopes to catalog and classify all of the stars and other objects visible from Earth. Scientists noticed that there was great variation in the brightness and color of stars. Spectroscopes, which split white light into its component colors like a rainbow, were used to further classify the stars into **spectral classes** (patterns of color distribution). Eventually, it was discovered that the color or spectral classes directly related to the **surface temperature** of the star, which seemed in some cases to also relate to the brightness of the star. For example, most blue-white stars were also very bright.
- Scientists during this time developed methods of estimating how far away a star was from Earth. By measuring the **apparent magnitude** (brightness) of the star,

its brightness as seen from Earth, and factoring in its distance from Earth, scientists could calculate their **absolute magnitude**, their actual brightness as judged from a standard distance. Another measure of absolute magnitude is **luminosity**, which compares other stars to our Sun—the luminosity of our Sun is 1, so luminosity states how many times brighter or dimmer another star is, as compared to our Sun.

- In the early 1900s, two scientists, **Ejnar Hertzsprung** in Denmark and **Henry Russell** in the United States, independently analyzed the relationship between absolute brightness and surface temperature in stars. The process that both used was to create a graph of absolute brightness or luminosity on the y-axis, and surface temperature or color on the x-axis. The immediate discovery that they made was that 90% of the stars they graphed had a direct relationship between absolute brightness and temperature: the hotter the surface temperature, the brighter the star. This graph, called the **Hertzsprung-Russell Diagram** or **H-R Diagram**, is still used by scientists today.
- These stars that had the direct relationship between absolute magnitude and temperature were called the **main sequence stars**, because the band on the graph contained 90% of the stars. Main sequence stars can range in luminosity from 1/10,000 of our Sun to 1000 times brighter. There is a direct relationship between luminosity and temperature, with brighter stars being hotter and the least bright stats being cooler.



- There were two concentrations of stars on the H-R Diagram that were generally brighter but cooler. These were named the giants and supergiants.
- On the H-R Diagram, **supergiants** have a luminosity of 1000 to 60,000 times brighter than our Sun, with surface temperatures ranging from 3000 K to 10,000 K.
- **Giants** have a luminosity of 10 to 100 times that of our Sun, with surface temperatures ranging from 3000 K to 6000 K.

- The fourth concentration of stars were generally low in brightness, but somewhat hotter. These **white dwarfs** are between 1/100 and 1/10,000 as bright as our Sun, with temperatures ranging from 4000 K to 20,000 K.
- Just as the patterns of the periodic table of the elements led to the discovery of the relationship between atomic structure and chemical properties, so too has the patterns of the H-R Diagram led to the discovery of the life-cycle of stars and four named stages.
- Based on analysis of the data contained in the H-R Diagram, scientists concluded that about 90% of a star's life is spent in a main sequence stage, the part of a star's life when it fuses hydrogen into helium.
- About 10% of the stars fell into two adjacent areas of stars that were generally brighter but cooler (redder). Scientists eventually concluded that these stars were in the last stages of their life, in which a series of elements heavier than hydrogen were being fused into still heavier elements.
- The hot but dim "stars" at the bottom of the H-R Diagram were eventually identified as the burned-out remains of small stars, called white dwarfs, no longer powered by fusion, but just a glowing ball of carbon. When a white dwarf eventually stops glowing and has become cold, it is called a **black dwarf.**

Life Cycle of Stars

- All stars begin their life when the gases (mostly hydrogen) and dust of a nebula are pulled together by gravity into a **protostar**. As the protostar collapses further, the center becomes hot enough to begin the fusion of hydrogen into helium. A main sequence star has now been born, and will spend the next 90% of its life in this stage. When all of the hydrogen has been fused, the star initially collapses, but then gets hot enough in its core to fuse helium into carbon. It is now a giant.
- Larger stars can go through this collapse and expansion process several times as a supergiant, fusing even heavier elements until iron is created. When no more fusion is possible, the star collapses and then explodes as a supernova, a massive explosion that spreads most of the star's mass over a huge area.
- From that point, the life-cycle of stars varies with the size (mass) of the star. Generally, small to average mass stars like our Sun follow a path that ends as a white dwarf and black dwarf. Larger stars having a mass of about 8 to 40 times that of our Sun end as **neutron star**, an extremely dense but small sphere made only of neutrons, about the size of Dallas but containing mass three or more times that of the Sun. The very largest stars, having a mass of more than 40 Suns, end as a **black hole**, which have so much mass compressed into such a small space that its gravity keeps even light from escaping.
- The life cycle of the three star sizes can be summarized as follows:
    - Small to Medium Star Life Cycle: (1) Nebula; (2) Main Sequence Star; (3) Giant; (4) White Dwarf; (5) Black Dwarf.
    - Large Star Life Cycle: (1) Nebula; (2) Main Sequence Star; (3) Supergiant; (4) Supernova; (5) Neutron Star.

- Very large Star Life Cycle: (1) Nebula; (2) Main Sequence Star; (3) Supergiant; (4) Supernova; (5) Black Hole.

Practice Questions

1. Scientists believe that the universe was created about ____________ billion years ago in an event known as the ________________ ______________________.
2. The _____________________________contains all of the matter and energy known by humans to exist.
3. A ______________________is a very large group of stars held together by gravity.
4. The galaxy in which we live is known as the ____________________ __________ galaxy, which contains about ____________ to ____________ billion stars.
5. The three types of galaxies are (1) __________________________, (2) _________________________ and (3) ____________________________________.
6. A ______________________ is a very large cloud of gas and dust.
7. The _________________________ magnitude of a star is the brightness of the star as seen from Earth.
8. The _________________________ magnitude of a star is its actual brightness, if viewed from a standard distance. This is also called ________________________, which compares the actual brightness to that of the Sun.
9. The __________________________ - ________________________ Diagram is a graph that compares _______________________________, plotted on the y-axis, with _______________________ or _________________________________, plotted on the x-axis.
10. There are four groups of stars on the H-R Diagram. About 90% of the stars are in the _________________________ ___________________________. The other 10% are in two areas, called the __________________________ and __________________________________. The fourth area at the bottom of the H-R Diagram contains the ___________________ __________________________, which are former stars that have stopped fusion but are still glowing from their left-over heat.
11. When white dwarfs stop glowing and become cold, they are called _________________ ______________________.

12. A ______________________ is a large explosion of a collapsing supergiant star which occurs when fusion stops.
13. A ______________________ __________________ is a very dense but small sphere made of neutrons.
14. A __________________ __________________ is an extremely dense area with gravity so intense that even light cannot escape.
15. The five life cycle stages for a small to medium star, no bigger than 8 times the mass of our Sun, are: (1) ______________________; (2) _______________ __________________ ____________; (3) ________________________; (4) ______________________ and (5) ___________________________.
16. The five life cycle stages for a large star, between 8 to 40 times the mass of our Sun, are: (1) ______________________; (2) _______________ __________________ ____________; (3) ________________________; (4) ______________________ and (5) ___________________________.
17. The five life cycle stages for a very large star, over 40 times the mass of our Sun, are: (1) ______________________; (2) _______________ __________________ ____________; (3) ________________________; (4) ______________________ and (5) ___________________________.