Astrobiology

An Integrated Science Approach

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TERC

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Activity Three

What Types of Stars are in Our Universe?

Purpose

To provide a sense of the abundance of different-colored stars and the relationship between color and temperature, mass, and age

Overview

Students are each given several star circles that include information about individual stars. They place these on a large class chart according to brightness and color (similar to an HR diagram). Discussion about the resulting chart involves trends between mass and color, temperature and color, and expected lifetime and color.

Time: 50 minutes

Context

Students should realize that the sun is only one type of star, and its type is not even the most abundant. Students will question whether the other types of stars could be suitable for supporting life in a solar system.

Key Concepts

- Stars come in many colors.
- A star's color is determined by its temperature.
- Hot stars generally have a shorter lifespan than cool stars.
- The sun is a yellow star, which is in the middle of the color and brightness spectrum, but yellow stars are not the most prevalent type in the universe.

Key Skills

- *Plotting* points on a graph
- *Analyzing* a graph to determine trends

Materials

- Scissors (for teacher)
- Large Poster Paper
- Markers
- Tape
- COLOR—*Star Circles*

Preparation

1. Cut out the *Star Circles* (COLOR).
2. Make a large plot on the classroom wall like the one on the *Star Chart Template*.

Recommended Procedures

1. Have your students attach the star circles on the wall chart.
   - Give out all the star circles to your students. There are 100 circles, so each student will get about 3-5, depending on the number of students in your class.
   - Have students first examine the star circles, looking at both their own and their neighbors'.
   - One at a time, have students position their circles on the chart, using the temperature and brightness axes to position them correctly. The purpose of this activity is to notice trends, so tell students not to get too bogged down in exact positioning of the stars on the plot, but to be careful that they place the stars in the right range, or else the patterns will get confusing.
   - Have students copy the chart into their journal.
2. Discuss the resulting chart with the class.
   - Describe the general trend between temperature and brightness.
   - What is the color and brightness of the most abundant stars? The rarest stars?
   - What are the characteristics of the stars that do not conform to the graph's trend?
   - In terms of the graph's trend, is our sun typical or exceptional?
   - If you replaced the temperature scale on the graph's x-axis with a color scale, which color would be closest to the graph's origin and which would farthest away?
   - In the stars that fit the general trend (these are often called Main Sequence stars), what relationship do you notice between color and expected lifetime?
3. Have students read *What's the Story? — What Is a Star?* and *What's the Story? — What Determines Habitable Zones Around Stars?* and answer the *Checking In* questions.
4. Have students answer the *Think About It* questions.

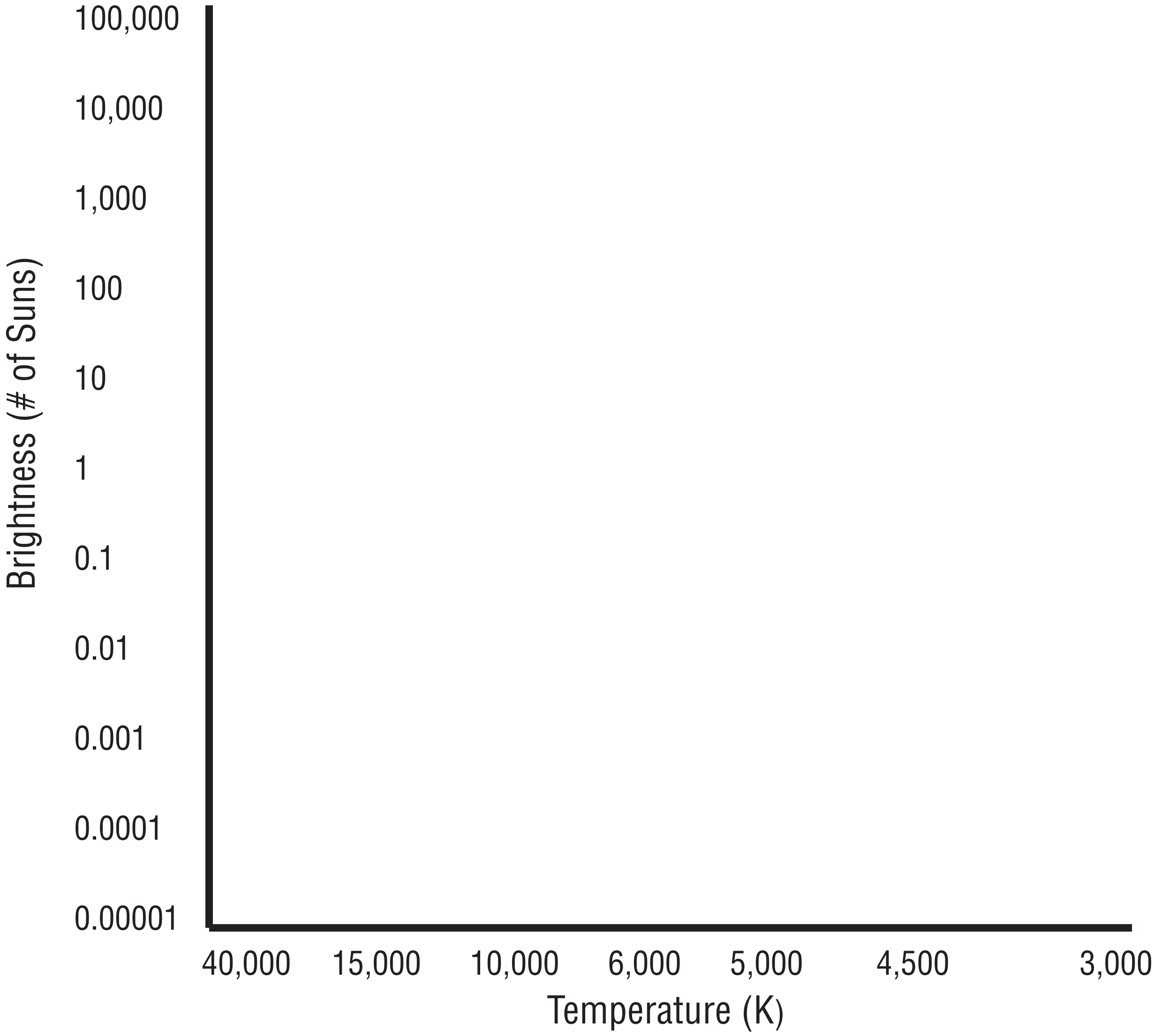
Think About It

1. Why might stars of one color be much more abundant than stars of another color?

   Since the red dim stars live the longest, there are many of them still around. The only hot blue stars we see are ones that formed in the past few million years. The others have already died off.
2. Which type(s) of star should we consider first when looking for stars that might have life-supporting worlds around them? Why?

   Since our sun is a yellow star, this is a good place to start, and in fact this is where many extrasolar planet searchers are looking. The blue and white stars are often ruled out because they don't live long enough for planetary life to begin and evolve very far before the star goes supernova. The red dim stars may not give off enough energy to support life easily on planets around them.

Star Chart Template



Notice that the axes are not scaled linearly. The vertical axis is brightness (in terms of number of times the brightness of our sun), and it is a geometric scale increasing by a factor of 10 each step. The horizontal axis is temperature (on the Kelvin scale) and it is roughly logarithmic. The graph is made this way to ensure that all the values fit within a reasonable area. It makes plotting the points more difficult for students, but they can approximate by doing a rough interpolation between numbers.

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Activity Three

What Types of Stars are in Our Universe?

Stars come in many different colors and sizes. We can determine a star's type by studying its color and brightness. Once we know a **star's type**, we can estimate its age, how long it lives, and the amount of energy it would provide to a nearby planet. This information is important to know when determining if a star could support life on an orbiting planet or moon.

> ***Learning Threads:* Structure of the Universe**
>
> *Stars differ from each other in size, temperature, and age.*

What You Need to Do

1. Examine the star circles your teacher gives you. Each circle has the following information.
   - **star name** – the common or catalog name of the star
   - **temperature** – the temperature of the surface of the star
   - **brightness** – the number of times brighter the star is than our sun (a fraction means it is dimmer than our sun)
   - **expected lifetime** –the number of years stars of this type are expected to exist at this color and brightness
2. When your teacher indicates, correctly position and attach your circles on the wall chart's temperature and brightness axes.
3. Once all the star circles are in place, sketch the axes and distribution of the stars in your journal. Discuss trends on the wall chart by considering the following questions:
   - Describe the general trend between temperature and brightness.
   - What is the color and brightness of the most abundant stars? The rarest stars?
   - What are the characteristics of the stars that do not conform to the graph's trend?
   - In terms of the graph's trend, is our sun typical or exceptional?
   - If you replaced the temperature scale on the graph's x-axis with a color scale, which color would be closest to the graph's origin and which would farthest away?
   - In the stars that fit the general trend (these are often called **main sequence** stars), what relationship do you notice between color and expected lifetime?
4. Read *What's the Story? — What Is a Star?* and answer the *Checking In* questions to understand more about how astronomers classify stars.
5. Read *What's the Story? — What Determines Habitable Zones Around Stars?* and answer the *Checking In* questions to understand more about how different types of stars affect habitability.
6. Answer the *Think About It* questions.

What's the Story?

Figure 2-8: This famous image from Hubble shows gaseous clouds giving rise to embryonic stars. This is part of the Eagle Nebula, or M16, a star-forming region 6,500 light years away.

What Is a Star?

Stars are hot, glowing balls of gas. They all begin as vast, hazy clouds of hydrogen and helium gas, light-years across in size. Occasionally, such clouds are jolted by the explosion of a nearby star or by a collision with a similar cloud or with a galaxy. The resulting violent shock wave buffets and compresses the cloud, causing it to clump into smaller clouds. The clumping of material also increases the gravitational pull of these smaller clouds. As a result, they attract and concentrate even more hydrogen and helium, becoming distinct and growing in size.

Inside each clump, gravity creates a very dense core where atoms constantly collide, generating very high temperatures. It is so hot and dense that hydrogen atoms smash into one another with enough force that they join together permanently. When two atoms combine, or fuse, they become a new, heavier kind of **element**, the simplest kind of matter. For instance, two hydrogen atoms may fuse together to form one helium atom. The process by which light elements fuse into heavier ones is called **nuclear fusion**. Nuclear fusion releases considerable amounts of energy. When the core of a clump becomes a hot, dense ball of hydrogen gas fusing into helium gas, a star is born.

Astronomers classify stars based on their age, color, and brightness. These characteristics help them identify and understand the different kinds of stars. A star's surface temperature determines the amount of visible light given off (its brightness) and the color we perceive the star to be. For example, yellow stars produce light of all colors, but the distribution causes our eyes to see more yellow light than any other color. White stars give off roughly equal amounts of every kind of light, and the blending of these colors makes them appear white. The hottest type of star appears blue or white, and the coolest type of star appears red. Brightness is related to a star's size, its distance from Earth, and its rate of fusion.

Our sun is often mistakenly called an "average" star. In fact, only about five percent of all stars are like our sun. Ninety-five percent of stars are bigger or smaller, hotter or cooler, brighter or dimmer, and more or less massive than our sun. If average means the kind of star you are most likely to find in our galaxy, then an average star would be a dim red one. There are very few hot, blue stars because they consume their fuel quickly and die. The expected lifetime of cool, dim, red stars is longer than the age of the universe! Since none have died yet, there are many around. In addition, over 50% of stars exist as pairs or in groups that can contain a few to thousands of stars. Our solitary, long-lived, medium-hot, yellow sun is a rarity in a universe filled with many distinctly non-sunlike stars.

✓✓✓✓✓ Checking In

1. What did our sun look like before it became a star?
2. Why can nuclear fusion occur in the core of a star?
3. What do color and brightness indicate about a star?
4. What is the most common type of star? Why?

What's the Story?

What Determines Habitable Zones Around Stars?

Astrobiologists define a habitable zone as a region around a star where some form of life could exist. In a habitable zone, the star supplies a planet enough energy so that it neither completely bakes nor freezes.

A habitable zone can be compared to sitting around a fire while camping in the dead of winter. If you sit too close to the campfire, you will burn. If you sit too far away, you will freeze. There is a narrow zone around the fire that would be considered just the right distance away.

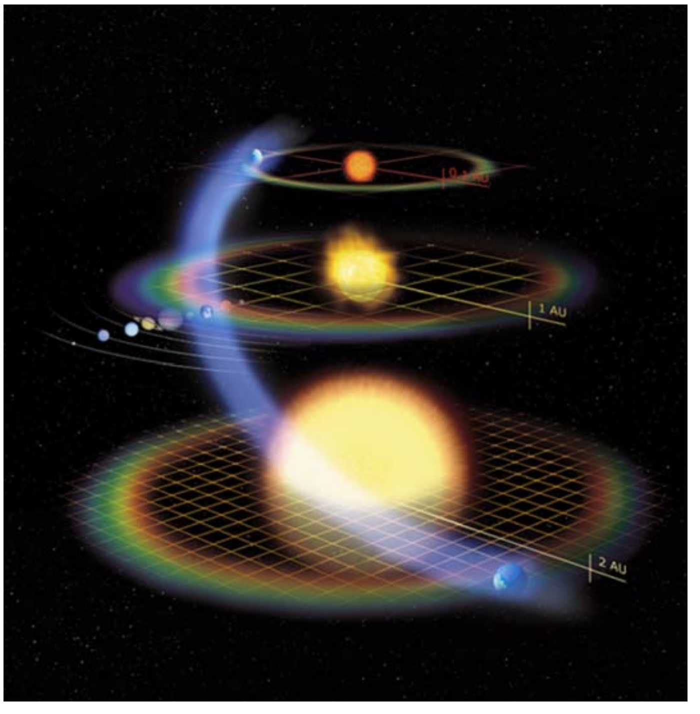

Figure 2-9: The habitable zone depends on the type of star around which planets orbit. With our sun, the zone for surface life puts Earth in the sweet spot for life. Other stars of different types would place the zone closer or farther away.

For a star like our sun, a yellow star with a surface temperature around 5,700° Celsius, the habitability zone is a narrow band just around the orbit of Earth. In fact, the two planets closest to Earth, Venus and Mars, seem to lie outside the sun's habitability zone for surface life. Venus is so hot that its surface water boiled away long ago. Except for brief moments at midday in the Martian summer, Mars is so cold that any water near the surface is frozen.

A star's habitable zone can be different sizes, depending on what kind of life-form you are considering. Both edges can be extended if you include life-forms such as microbes, which can tolerate conditions that surface life and more complex organisms cannot. The narrowest habitable zone is the one that maintains conditions suitable for surface life. Surface life requires appropriate temperatures, shielding from harmful solar radiation, and a star that gives off dependable, constant amounts of energy.

The habitable zone around stars hotter than our sun would be farther out than the one in our solar system. However, the expected lifetime of a hot star is relatively short, and life may not have time to start or evolve before the hot star dies. As it turns out, over ninety-five percent of all stars are smaller and cooler than our sun. Any planets around such stars would have to orbit very close to the star to be in its habitable zone. However, orbiting close to a star is dangerous. Planets very close to a star become **tidally locked**, meaning that the same side of a planet always faces the star. Thus, one side of such a world has constant day while the other side remains in continuous night. The temperature extremes on each side are not conducive for life.

For a variety of reasons, many stars in the universe have no habitable zone. For example, most stars exist in groups of two or more, making it difficult for a planet to have a stable orbit with just the right amount of constant starlight to be habitable. Frank Drake, author of the Drake equation, chose M13, a dense cluster of millions of stars, for the target of one of his first attempts to contact extraterrestrial life. Because of the many hazards associated with multiple star systems, we now know that M13 was not a wise choice. Today, astrobiologists search for habitable zones around individual, sun-like stars.

✔✔✔✔✔ Checking In

1. The sun's habitable zone is sometimes likened to the story in which Goldilocks says the porridge is too hot, too cold, and just right. Which planets fit this Goldilocks analogy?
2. Why can a star have several different habitable zones?
3. What kinds of stars have either no habitable zones or very inferior ones?

Think and Reflect

Think About It

1. Why might stars of one color be much more abundant than stars of another color?
2. Which type(s) of star should we consider first when looking for stars that might have life-supporting worlds around them? Why?

Reflecting on the Activity and the Challenge

Our sun is one of many stars in the universe. Understanding what a star's age, color, and temperature tell you can help you determine if the star might have worlds that could support life orbiting around it. What kind of star would you choose to support the world that you are designing? Does the kind of star have any impact on the size of the world you are designing?

Star Circles

PL00932
Brightness: 0.5 Suns
Temperature: 5,200 K

Betelgeuse
Brightness: 9000 Suns
Temperature: 3,000 K

Alpheratz
Brightness: 132 Suns
Temperature: 22,000 K
Lifetime: 10^5 yrs

Mu Geminorum
Brightness: 310 Suns
Temperature: 3,100 K

Wezen
Brightness: 60000 Suns
Temperature: 6,000 K

Ruchbah
Brightness: 70 Suns
Temperature: 15,000 K
Lifetime: 10^8 yrs

Arneb
Brightness: 10,000 Suns
Temperature: 7,300 K

Procyon
Brightness: 8 Suns
Temperature: 8,600 K
Lifetime: 10^9 yrs

Kaffaljidhma
Brightness: 25 Suns
Temperature: 14,000 K
Lifetime: 10^8 yrs

Sirius
Brightness: 23 Suns
Temperature: 9,800 K

Castor
Brightness: 19 Suns
Temperature: 9,800 K

Hassaleh
Brightness: 3 Suns
Temperature: 8,300 K
Lifetime: 10^9yrs

APAC617

Brightness: 0.02 Suns

Temperature: 4,100 K

Lifetime: 10^{10} yrs

BDE10298

Brightness: 0.01 Suns

Temperature: 3,900 K

Lifetime: 10^{10} yrs

APAC424

Brightness: 0.01 Suns

Temperature: 3,900 K

Lifetime: 10^{11} yrs

DC0032864

Brightness: 0.06 Suns

Temperature: 4,200 K

Lifetime: 10^{11} yrs

KO65430

Brightness: 0.01 Suns

Temperature: 3,500 K

Lifetime: 10^{10} yrs

DC0029876

Brightness: 0.04 Suns

Temperature: 4,300 K

Lifetime: 10^{11} yrs

JAC76582

Brightness: 0.04 Suns

Temperature: 3,800 K

Lifetime: 10^{11} yrs

CRTP987

Brightness: 0.08 Suns

Temperature: 3,600 K

Lifetime: 10^{11} yrs

JAC39672

Brightness: 0.02 Suns

Temperature: 3,900 K

Lifetime: 10^{11} yrs

JAC12967

Brightness: 0.09 Suns

Temperature: 4,200 K

Lifetime: 10^{11} yrs

DAAC329

Brightness: 0.09 Suns

Temperature: 4,200 K

Lifetime: 10^{11} yrs

JAC43928

Brightness: 0.07 Suns

Temperature: 4,100 K

Lifetime: 10^{11} yrs

Phaet

Brightness: 480 Suns

Temperature: 20,000 K

Lifetime: 10^{0} yrs

Mintaka

Brightness: 10,000 Suns

Temperature: 40,000 K

Lifetime: 10^{4} yrs

Sun

Brightness: 1 Suns

Temperature: 4,800 K

Lifetime: 10^{10} yrs

Proxima

Brightness: 0.00005 Suns

Temperature: 2,900 K

Lifetime: 10^{11} yrs

Barnard s

Brightness: 0.0003 Suns

Temperature: 3,000 K

Lifetime: 10^{11} yrs

Mirach

Brightness: 480 Suns

Temperature: 3,200 K

Wolf 359

Brightness: 0.00002 Suns

Temperature: 2,900 K

Lifetime: 10^{11} yrs

BD + 362147

Brightness: 0.005 Suns

Temperature: 3,500 K

Lifetime: 10^{11} yrs

Sheratan

Brightness: 25 Suns

Temperature: 12,000 K

Lifetime: 10^{9} yrs

L726-8A

Brightness: 0.00006 Suns

Temperature: 3,000 K

Lifetime: 10^{10} yrs

L726-8B

Brightness: 0.00005 Suns

Temperature: 3,000 K

Lifetime: 10^{10} yrs

Acamar

Brightness: 110 Suns

Temperature: 20,000 K

Lifetime: 10^{6} yrs

Ross 154

Brightness: 0.0005 Suns

Temperature: 3,000 K

Lifetime: 10^{11} yrs

Ross 248

Brightness: 0.0004 Suns

Temperature: 3,000 K

Lifetime: 10^{11} yrs

BD591915A

Brightness: 0.0006 Suns

Temperature: 3,100 K

Lifetime: 10^{11} yrs

Epsilon Eri

Brightness: 0.28 Suns

Temperature: 4,200 K

Lifetime: 10^{10} yrs

CD3615693

Brightness: 0.0001 Suns

Temperature: 3,300 K

Lifetime: 10^{11} yrs

Epsilon Indus

Brightness: 0.16 Suns

Temperature: 4,200 K

Lifetime: 10^{10} yrs

Ross 128

Brightness: 0.0003 Suns

Temperature: 3,200 K

Lifetime: 10^{11} yrs

L789ABC

Brightness: 0.0001 Suns

Temperature: 3,200 K

Lifetime: 10^{11} yrs

L37258

Brightness: 0.0001 Suns

Temperature: 3,200 K

Lifetime: 10^{11} yrs

61CygA

Brightness: 0.04 Suns

Temperature: 4,200 K

Lifetime: 10^{10} yrs

61CygB

Brightness: 0.05 Suns

Temperature: 4,200 K

Lifetime: 10^{10} yrs

BD51668

Brightness: 0.0006 Suns

Temperature: 3,000 K

Lifetime: 10^{11} yrs

B0591915B

Brightness: 0.0005 Suns

Temperature: 3,000 K

Lifetime: 10^{11} yrs

XL9876-1

Brightness: 0.5 Suns

Temperature: 5,500 K

Lifetime: 10^{10} yrs

XL9473-1

Brightness: 0.6 Suns

Temperature: 6,100 K

Lifetime: 10^{10} yrs

G5115

Brightness: 0.00001 Suns

Temperature: 2,900 K

Lifetime: 10^{11} yrs

GL86715

Brightness: 1.1 Suns

Temperature: 5,900 K

Lifetime: 10^{10} yrs

SL9-67294

Brightness: 1.6 Suns

Temperature: 6,200 K

Lifetime: 10^{10} yrs

Tau Cetus

Brightness: 0.5 Suns

Temperature: 5,200 K

Lifetime: 10^{10} yrs

YEZ8732

Brightness: 0.8 Suns

Temperature: 5,400 K

Lifetime: 10^{10} yrs

XXR42

Brightness: 19 Suns

Temperature: 9,200 K

Lifetime: 10^{9} yrs

L72532

Brightness: 0.0002 Suns

Temperature: 2,900 K

Lifetime: 10^{11} yrs

XXR49

Brightness: 22 Suns

Temperature: 9,900 K

Lifetime: 10^{9} yrs

XXR86

Brightness: 66 Suns

Temperature: 10,000 K

Lifetime: 10^{9} yrs

PL0089
Brightness: 0.3 Suns
Temperature: 4,800 K
Lifetime: 10^{10} yrs

BLG9982
Brightness: 0.009 Suns
Temperature: 3,000 K
Lifetime: 10^{11} yrs

SAC2243
Brightness: 29 Suns
Temperature: 9,400 K
Lifetime: 10^{9} yrs

MGU82067
Brightness: 0.0001 Suns
Temperature: 3,100 K
Lifetime: 10^{11} yrs

WZ443
Brightness: 60 Suns
Temperature: 9,000 K
Lifetime: 10^{7} yrs

SAC9899
Brightness: 72 Suns
Temperature: 10,400 K
Lifetime: 10^{9} yrs

ARN93227
Brightness: 0.7 Suns
Temperature: 5,000 K
Lifetime: 10^{10} yrs

PY7Z91
Brightness: 80 Suns
Temperature: 9,600 K
Lifetime: 10^{7} yrs

YEZ8872
Brightness: 88 Suns
Temperature: 10,400 K
Lifetime: 10^{9} yrs

G757
Brightness: 2.3 Suns
Temperature: 5,800 K
Lifetime: 10^{10} yrs

CST6128
Brightness: 1.9 Suns
Temperature: 5,800 K
Lifetime: 10^{10} yrs

SAC5430
Brightness: 28 Suns
Temperature: 9,700 K
Lifetime: 10^{9} yrs

Kapteyn s
Brightness: 0.004 Suns
Temperature: 3,500 K
Lifetime: 10^{11} yrs

CD3914192
Brightness: 0.03 Suns
Temperature: 3,600 K
Lifetime: 10^{10} yrs

BSC3430
Brightness: 3 Suns
Temperature: 5,900 K
Lifetime: 10^{10} yrs

Kruger 60A
Brightness: 0.0006 Suns
Temperature: 3,200 K
Lifetime: 10^{11} yrs

Krugar 60B
Brightness: 0.00008 Suns
Temperature: 3,100 K
Lifetime: 10^{11} yrs

LP033276
Brightness: 0.001 Suns
Temperature: 11,100 K

CD2510553
Brightness: 0.00004 Suns
Temperature: 3,000 K
Lifetime: 10^{11} yrs

Ross 614A
Brightness: 0.00007 Suns
Temperature: 3,000 K
Lifetime: 10^{11} yrs

RTL9847
Brightness: 2 Suns
Temperature: 6,000 K
Lifetime: 10^{10} yrs

Ross 614B
Brightness: 0.00001 Suns
Temperature: 2,900 K
Lifetime: 10^{11} yrs

BD51668
Brightness: 0.0006 Suns
Temperature: 3,000 K
Lifetime: 10^{11} yrs

DAAC328
Brightness: 1.6 Suns
Temperature: 6,200 K
Lifetime: 10^{10} yrs

APAC529
Brightness: 1.7 Suns
Temperature: 6,100 K
Lifetime: 10^{10} yrs

BDE00017
Brightness: 1.0 Suns
Temperature: 5,900 K
Lifetime: 10^{10} yrs

Beta Sagittae
Brightness: 300 Suns
Temperature: 6,000 K

DC0020938
Brightness: 320 Suns
Temperature: 3,200 K

K073491
Brightness: 120 Suns
Temperature: 35,000 K
Lifetime: 10^{6} yrs

PG000017
Brightness: 0.0002 Suns
Temperature: 10,200 K

JAC64932
Brightness: 101 Suns
Temperature: 38,000 K
Lifetime: 10^{6} yrs

RTL6439
Brightness: 81 Suns
Temperature: 26,000 K
Lifetime: 10^{7} yrs

JAC57492
Brightness: 1.2 Suns
Temperature: 5,900 K
Lifetime: 10^{10} yrs

JAC04320
Brightness: 90 Suns
Temperature: 22,000 K
Lifetime: 10^{7} yrs

DAAC444
Brightness: 0.09 Suns
Temperature: 4,100 K
Lifetime: 10^{10} yrs

JAC7632
Brightness: 0.8 Suns
Temperature: 5,900 K
Lifetime: 10^{10} yrs