Appendix A: Stellar Life Cycle Stages

STELLAR NEBULA

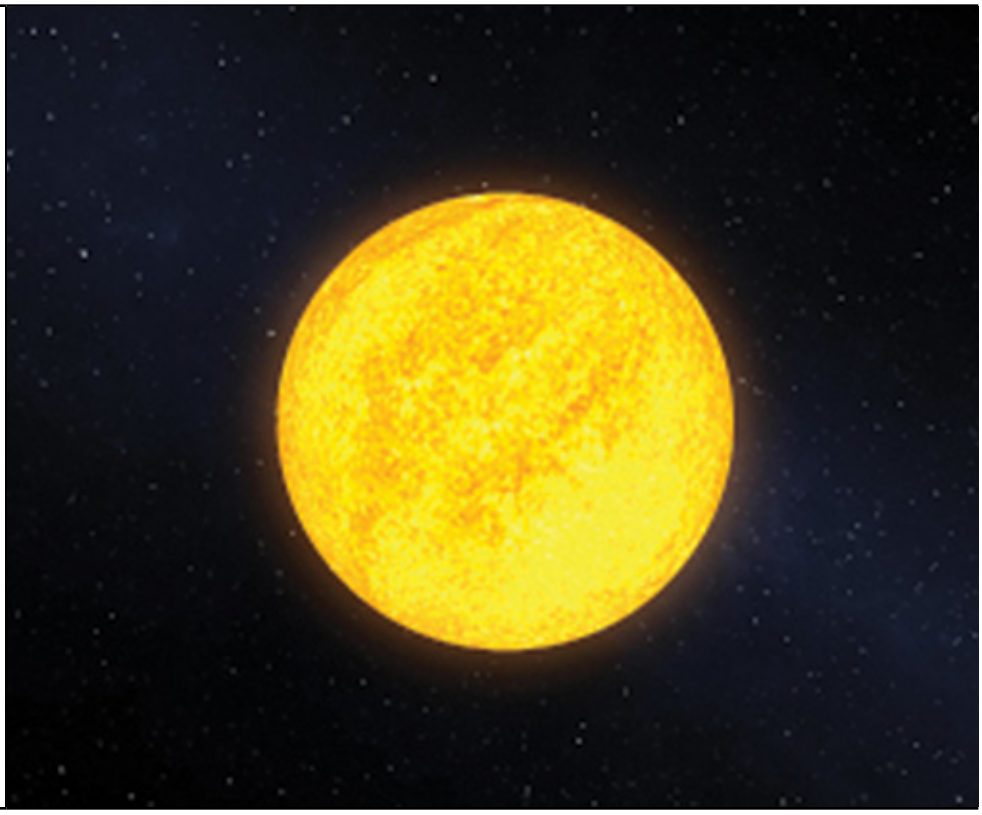
A STELLAR NEBULA is the birthplace of stars. These giant gas clouds in space are mostly hydrogen gas. Gravity clumps the hydrogen atoms together. Once enough gas has been collected, the gravitational force becomes so strong that hydrogen atoms fuse into helium through nuclear fusion, releasing energy in the process. A star is born. Stars come in various sizes and colours, depending on the initial amount of hydrogen gas collected.

Credit: NASA, ESA, the Hubble Heritage Team (STScI/AURA), A. Nota (ESA/STScI), and the Westerlund 2 Science Team

AVERAGE STAR

An AVERAGE STAR, such as the Sun, is in a constant tug-of-war between forces that allow it to remain stable. The energy released by nuclear fusion creates an outward force. However, gravity counteracts this outward force by applying its own inward force, keeping everything in balance.

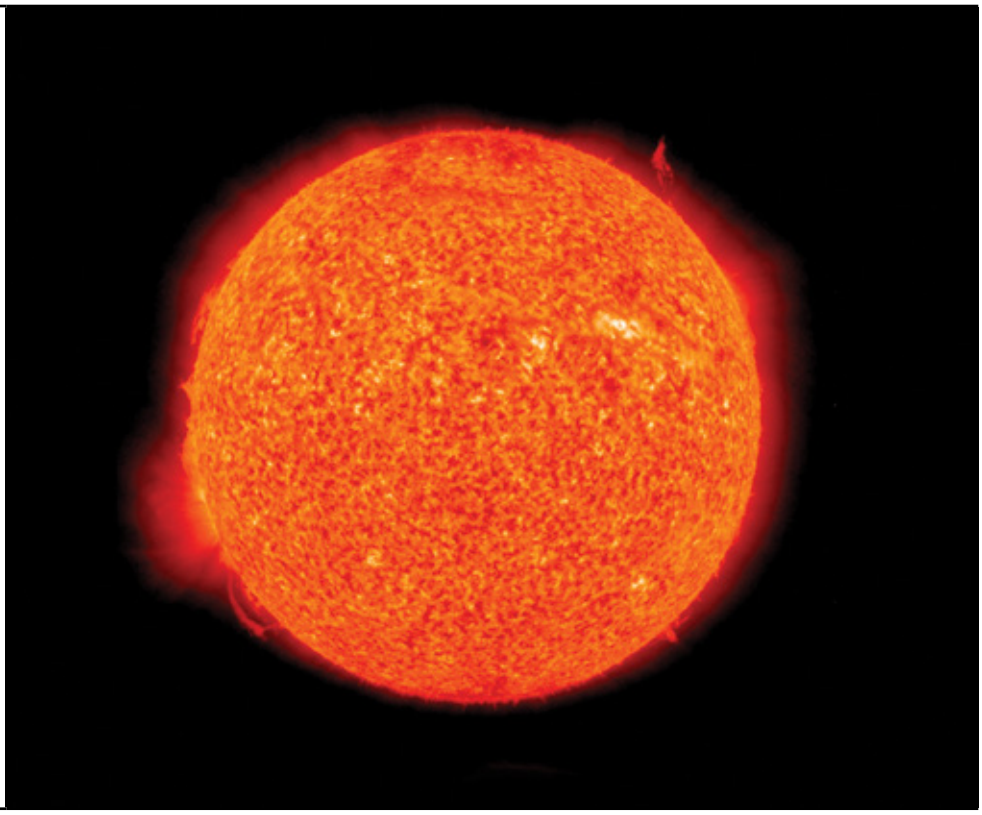
Credit: NASA/Kepler Mission/Dana Berry



RED GIANT

As an average star begins to run out of fuel, it will expand to become a RED GIANT. The pressure inside causes the star to swell to enormous proportions, typically hundreds of times larger than the original star. When the Sun becomes a red giant in about 5 to 6 billion years, it will expand enough to approximately reach Earth's orbit.

Credit: NASA/KASC



PLANETARY NEBULA

Later in its lifetime, a red giant becomes unstable and disintegrates. The internal nuclear pressure will blow off much of the outside layers of the star into space. Gravity will still confine a solid core, left over in the centre. The gas that has been blown off is called a PLANETARY NEBULA.

Credit: C.R. O'Dell, (Vanderbilt) et al. ESA, NOAO, NASA

WHITE DWARF

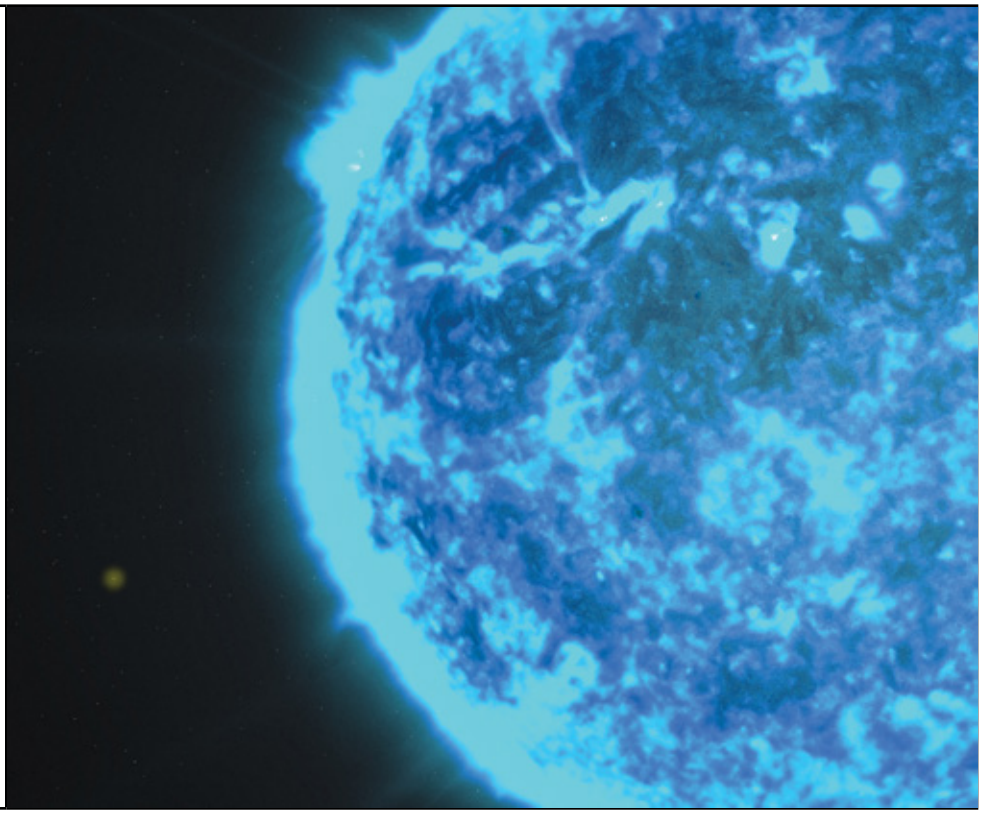
The leftover core of a red giant is called a WHITE DWARF. White dwarfs have a mass close to the mass of the Sun, but packed into the volume of Earth, therefore making them very dense. After a lifetime of fusing hydrogen to make heavier elements, white dwarfs are mostly composed of carbon and oxygen. A white dwarf will continue to produce light for many billions of years as it cools.

Credit: NASA, ESA, and G. Bacon (STScI)

MASSIVE STAR

MASSIVE STARS can form from a stellar nebula and are much larger than the Sun. Compared to average stars, massive stars burn their hydrogen fuel much more quickly, making them hotter and bluish in colour, and giving them shorter lifespans.

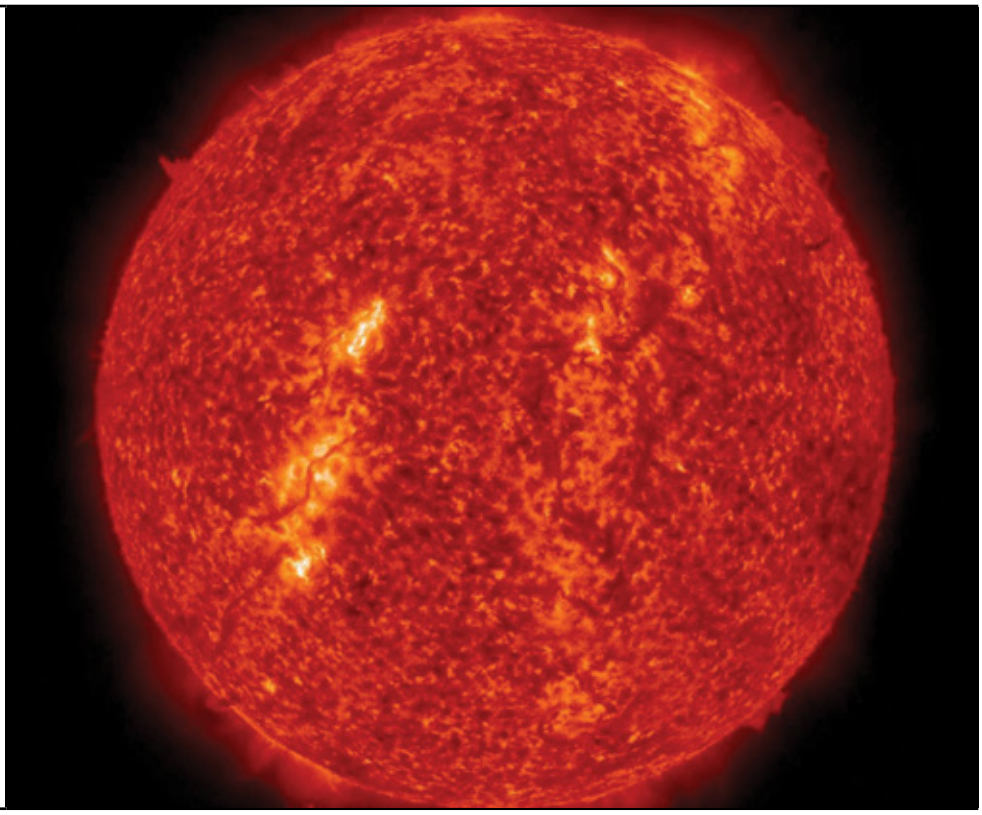
Credit: NASA's Goddard Space Flight Center/S. Wiessinger



RED SUPERGIANT

When a massive star begins to run out of fuel, it will grow to an enormous volume and become a RED SUPERGIANT. Red supergiants are some of the largest stars known. Because of their initial masses, they are able to build up and store heavier elements in their cores, such as magnesium, titanium, and iron.

Credit: NASA/SDO



SUPERNOVA

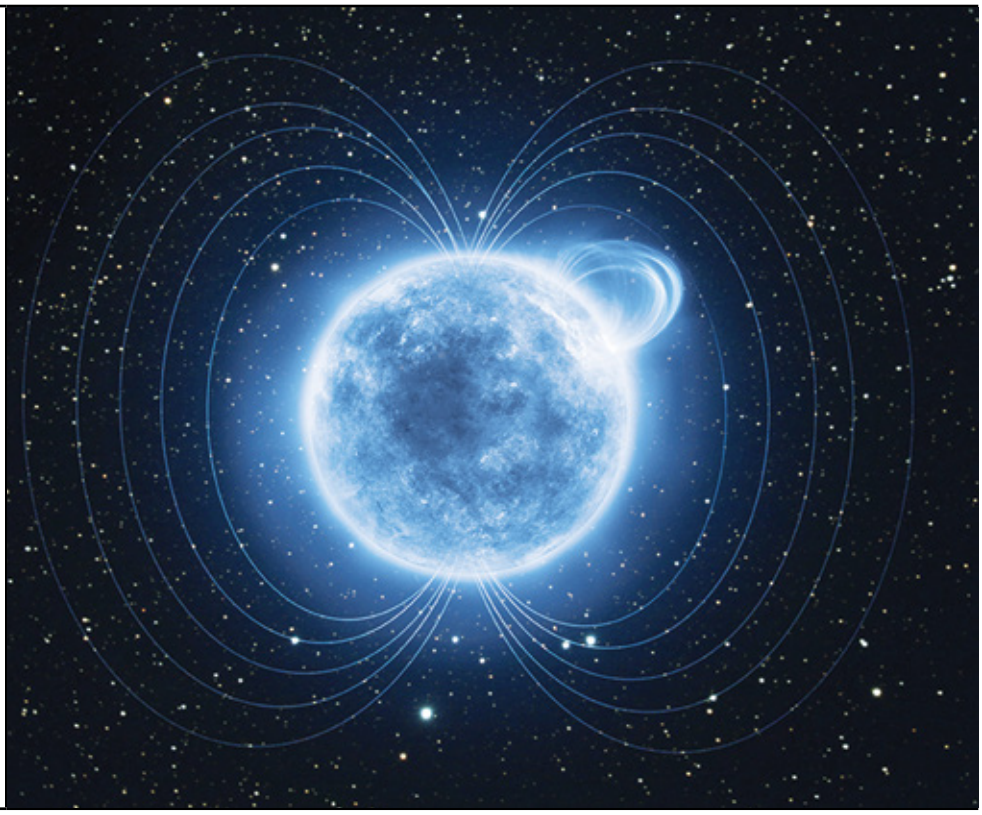
After the red supergiant stage of a massive star, the star will end its life in a violent explosion called a SUPERNOVA (shown in the lower right corner of the image). Layers of heavier elements stacked upon each other at the core of the star collapse due to gravity since they are no longer supported by outward nuclear pressure. As the elements fall down onto each other, they rebound out from the core, producing an enormous explosion of matter, light, and energy.

Credit: High-Z Supernova Search Team, HST, NASA

NEUTRON STAR

A NEUTRON STAR is a what remains after a massive star has become a supernova. Gravity is so incredibly strong that it makes the electrons combine with the protons in each atom to create neutrons. Neutron stars spin incredibly quickly, have enormous magnetic fields, and are some of the densest objects in the universe. The radius of a typical neutron star is only 10 km. A smartphone with the same density as a neutron star would have a mass of approximately 10 billion tonnes!

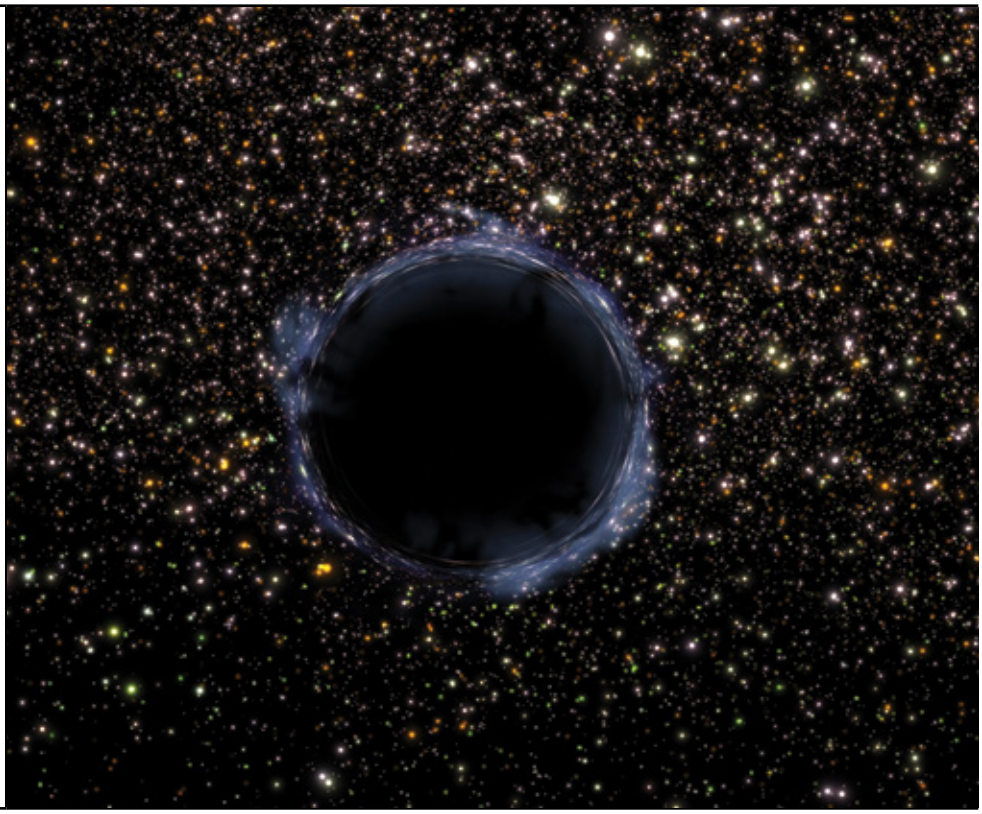
Credit: ESA/ATG medialab



BLACK HOLE

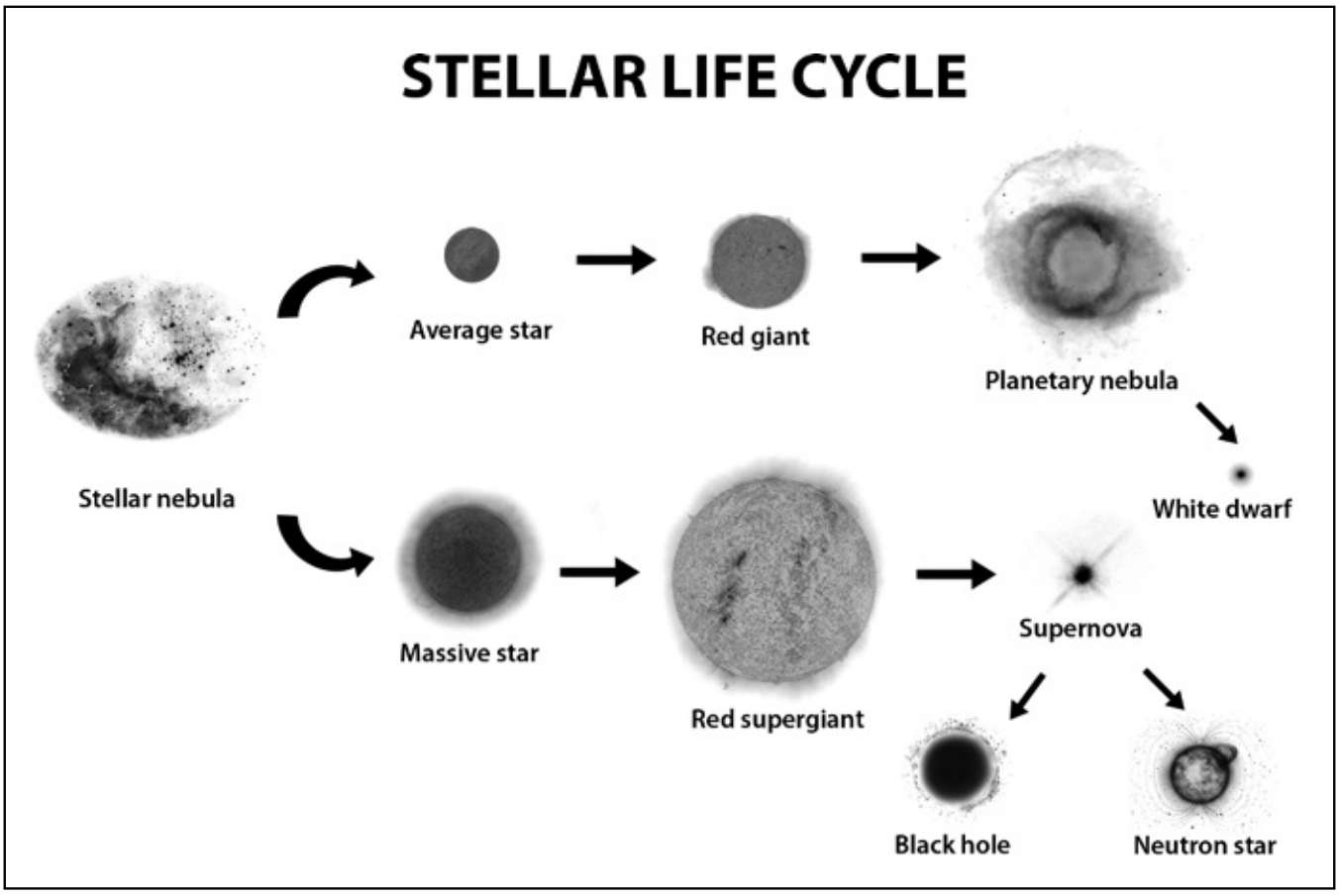
If a red supergiant is massive enough following the supernova explosion, what remains will become gravitationally crushed, warping space and time to the point where nothing, not even light, can escape its gravity. The leftover matter will collapse into a singularity with infinite density, leaving a void in space. This is called a BLACK HOLE.

Credit: NASA/ESA and G. Bacon (STScI)



Appendix B: Stellar Life Cycle Summary

Activity 1



Appendix C: Stellar Data Cards

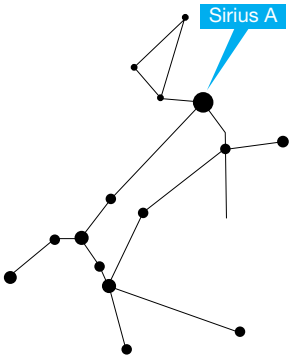
Activity 1 (Set 1: Star Cards)

SIRIUS A

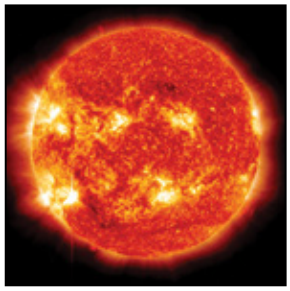
Credit: NASA, ESA, and G. Bacon (STScI)

Name: Sirius A
Object: Star
Mass: 2.02 M_{SUN}
Temperature: 9670°C
Colour: Blue
Death Outcome: White Dwarf

CANIS MAJOR



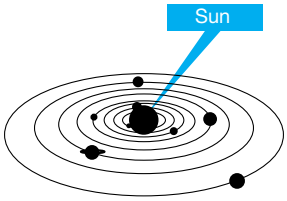
SUN



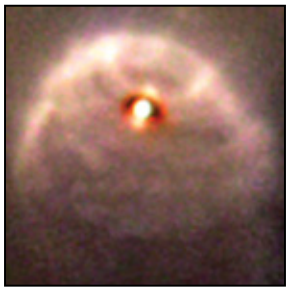
Credit: NASA/SDO

Name: Sun
Object: Star
Mass: 1.0 M_{SUN}
Temperature: 5500°C
Colour: Yellow
Death Outcome: White Dwarf

SOLAR SYSTEM



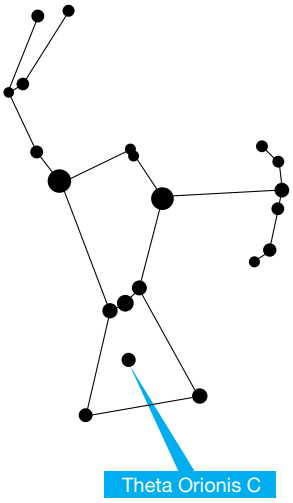
THETA ORIONIS C



Credit: NASA/ESA and L. Ricci (ESO)

Name: Theta Orionis C
Object: Star
Mass: 40 M_{SUN}
Temperature: 40 000°C
Colour: Blue
Death Outcome: Black Hole

ORION

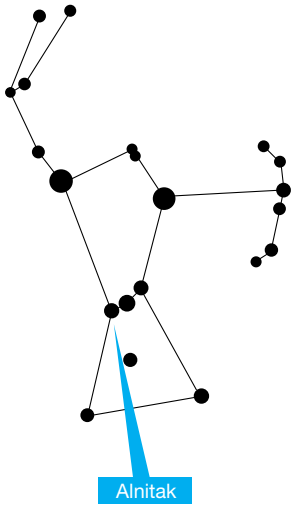


ALNITAK

Credit: Digitized Sky Survey, ESA/ESO/NASA FITS Liberator

Name: Alnitak
Object: Star
Mass: 33 M_{SUN}
Temperature: 28 000°C
Colour: Blue
Death Outcome: Black Hole

ORION

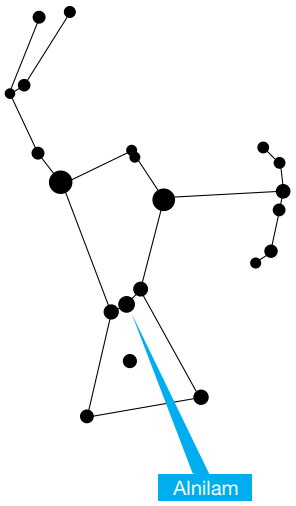


ALNILAM

Credit: Digitized Sky Survey, ESA/ESO/NASA FITS Liberator

Name: Alnilam
Object: Star
Mass: 24 M_{SUN}
Temperature: 27 000°C
Colour: Blue
Death Outcome: Neutron Star

ORION

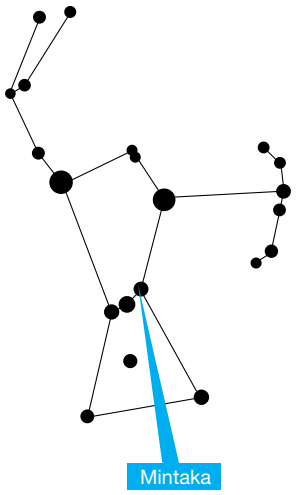


MINTAKA

Credit: Digitized Sky Survey, ESA/ESO/NASA FITS Liberator

Name: Mintaka
Object: Star
Mass: 20 M_{SUN}
Temperature: 29 000°C
Colour: Blue
Death Outcome: Neutron Star

ORION

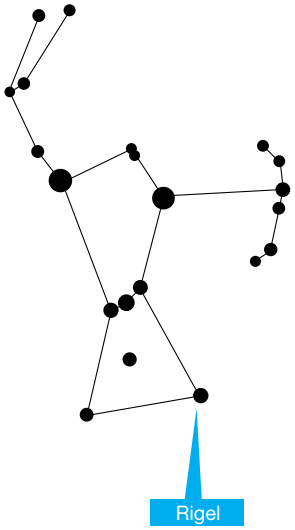


RIGEL

Credit: Rogelio Bernal Andreo/ Creative Commons

Name: Rigel
Object: Star
Mass: 21 M_{SUN}
Temperature: 11 800°C
Colour: Blue
Death Outcome: Neutron Star

ORION

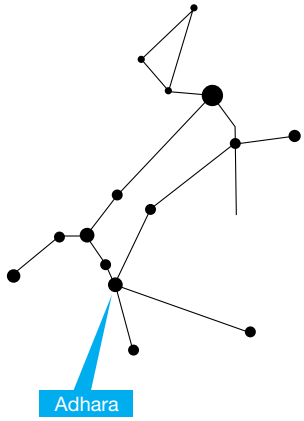


ADHARA

Credit: David Darling

Name: Adhara
Object: Star
Mass: 12.6 M_{SUN}
Temperature: 22 000°C
Colour: Blue
Death Outcome: Neutron Star

CANIS MAJOR

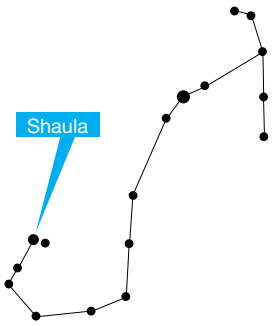


SHAULA

Credit: Akira Fujii/Creative Commons

Name: Shaula
Object: Star
Mass: 10.4 M_{SUN}
Temperature: 24 700°C
Colour: Blue
Death Outcome: Neutron Star

SCORPIUS

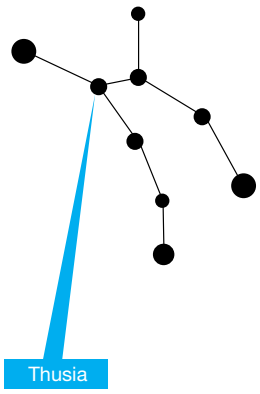


THUSIA

Credit: NASA and ESA

Name: Thusia
Object: Star
Mass: 9.5 M_{SUN}
Temperature: 21 000°C
Colour: Blue
Death Outcome: White Dwarf

LUPUS

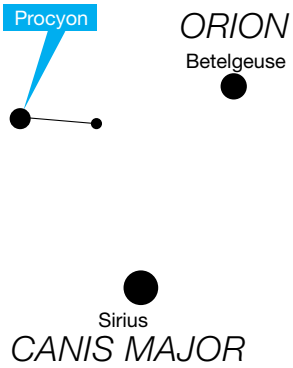


PROCYON

Credit: Akira Fujii/Creative Commons

Name: Procyon
Object: Star
Mass: 1.42 M_{SUN}
Temperature: 6260°C
Colour: Yellow
Death Outcome: White Dwarf

CANIS MINOR

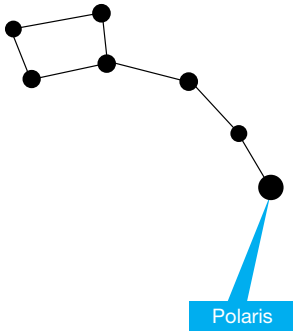


POLARIS

Credit: NASA, ESA, G. Bacon (STScI)

Name: Polaris
Object: Star
Mass: 4.5 M_{SUN}
Temperature: 5745°C
Colour: Yellow
Death Outcome: White Dwarf

URSA MINOR

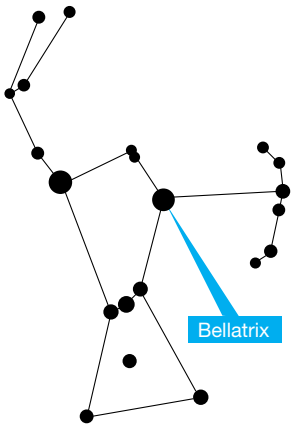


BELLATRIX

Credit: Rogelio Bernal Andreo/ Creative Commons

Name:	Bellatrix
Object:	Star
Mass:	8.4 M_{SUN}
Temperature:	22 000°C
Colour:	Blue
Death Outcome:	White Dwarf

ORION

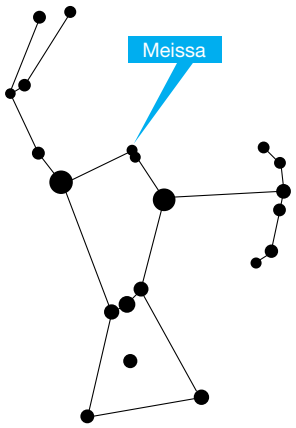


MEISSA

Credit: Rogelio Bernal Andreo/ Creative Commons

Name:	Meissa
Object:	Star
Mass:	28 M_{SUN}
Temperature:	35 000°C
Colour:	Blue
Death Outcome:	Black Hole

ORION



Appendix C: Stellar Data Cards

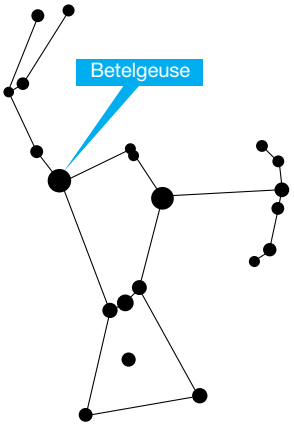
Activity 1 (Set 2: Tester Cards)

BETELGEUSE

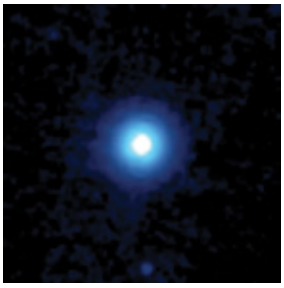
Credit: Rogelio Bernal Andreo/ Creative Commons

Name: Betelgeuse
Object: Red Supergiant
Mass: 20 M_{SUN}
Temperature: 3230°C
Colour: Red
Death Outcome: ?

ORION



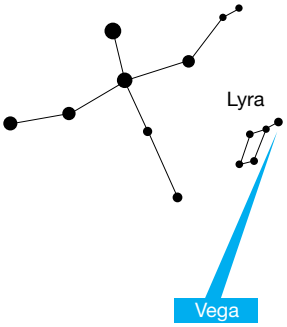
VEGA



Credit: NASA/JPL-Caltech/ University of Arizona

Name: Vega
Object: Star
Mass: 2.1 M_{SUN}
Temperature: 9330°C
Colour: Yellow
Death Outcome: ?

CYGNUS

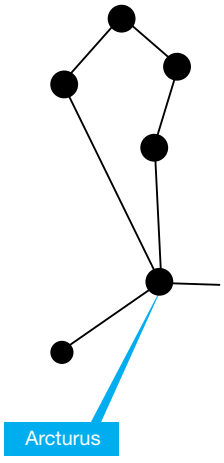


ARCTURUS

Credit: DSS2/MAST/STScI/NASA

Name: Arcturus
Object: Red Giant
Mass: 1.08 M_{SUN}
Temperature: 4000°C
Colour: Orange
Death Outcome: ?

BOOTES

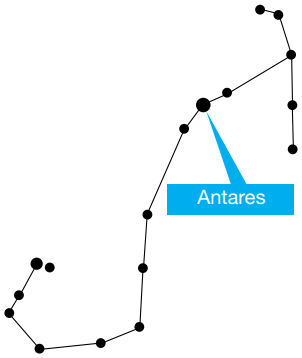


ANTARES

Credit: Akira Fujii/Creative Commons

Name: Antares
Object: Red Supergiant
Mass: 12.4 M_{SUN}
Temperature: 3100°C
Colour: Yellow
Death Outcome: ?

SCORPIUS



SUPERNOVA 1994D

Credit: NASA, ESA, The Hubble Key Project Team, and The High-Z Supernova Search Team

Name:	Supernova 1994D
Object:	Supernova
Mass:	N/A
Temperature:	N/A
Colour:	N/A
Death Outcome:	?

VIRGO