Habitable Zones in Binary Systems

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Rationale

There is a strong need for further research about habitable zones in binary systems and whether these systems have a chance at hosting life. It is important for us to know if there is life in binary systems because it can tell us more about Earth’s history, the Sun’s history, as well as more about the universe as a whole.

Rationale Continued

I chose to do a project about binary stars, their orbits, and how this affects their habitable zones because I have a great passion for astronomy; I also believe that the information gathered in this research could have profound implications on Earth Science studies.

This research project can help further the knowledge of astronomy and astrophysics by showing how binary stars and their habitable zones work and are affected.

Testable Question

In a circumbinary system, how far is the planetary habitable zone from the stars, and how does the type of stars in the system affect where the habitable zone is?

Hypothesis

If circumbinary systems are known to have habitable zones then binary systems that have simular qualities to the sun are more likely to have life-bound habitable zones. I predict these planets will have a habitable zone of about 0.5 AU away from the star. I hypothesize that 2 out of the 3 planets in the binary systems will have red dwarf stars as their host. The type of the star will be found based on the data collected.

Variables

Independent Variables - Kepler 38 System, Kepler 16 System, Kepler 47 System (Circumbinary Systems with an Earth-like planet in habitable zone)

Dependent Variables - Starting and ending points of the habitable zone, classes of the stars, and characteristics of the stars in the systems.

Control - The Sun (has a planet, Earth, in the habitable zone)

Background Knowledge

Binary Systems: a star system with two host stars.

Circumbinary Systems: Are binary systems with a planet orbiting both stars.

Different star types have different temperatures and different sizes along with many other factors (refer to the Schematic Hertzsprung-Russel Diagram)

Common Star Types

M Class - Red Dwarf

K Class - Orange Dwarf

G Class - Yellow Dwarf

White Dwarf

Red Giant

Red Supergiant

Background Knowledge Continued

Mass- the amount of matter in a star, also relates to how much gravitational pull or attraction to other stellar bodies.

Temperature- how hot the surface of the star is, measured in Kelvin.

Luminosity- the amount of light emitted from a star’s surface.

Eccentricity- the measurement of how far the orbit is from a perfect circular orbit.

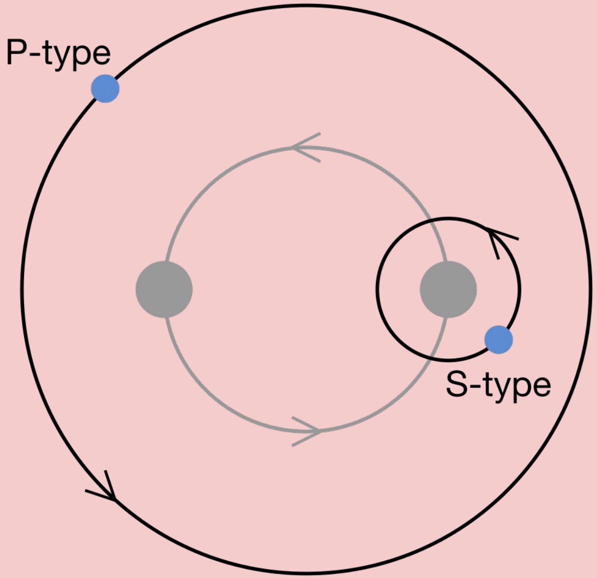
Semi-Major Axis- the distance from the middle point of the ellipse to one of the endpoints in the ellipse.

All About Binary Systems

A binary system is a star system where 2 stars orbit around a common center of mass.

Around 85% of the stars in the night sky are binary, so it would make sense to look at these for signs of life rather than the other 15%.

There are 2 types of binary systems- P-type and S-type. A P-type is when a planet goes around both stars. An S-type is when the planet only goes around one of the stars.



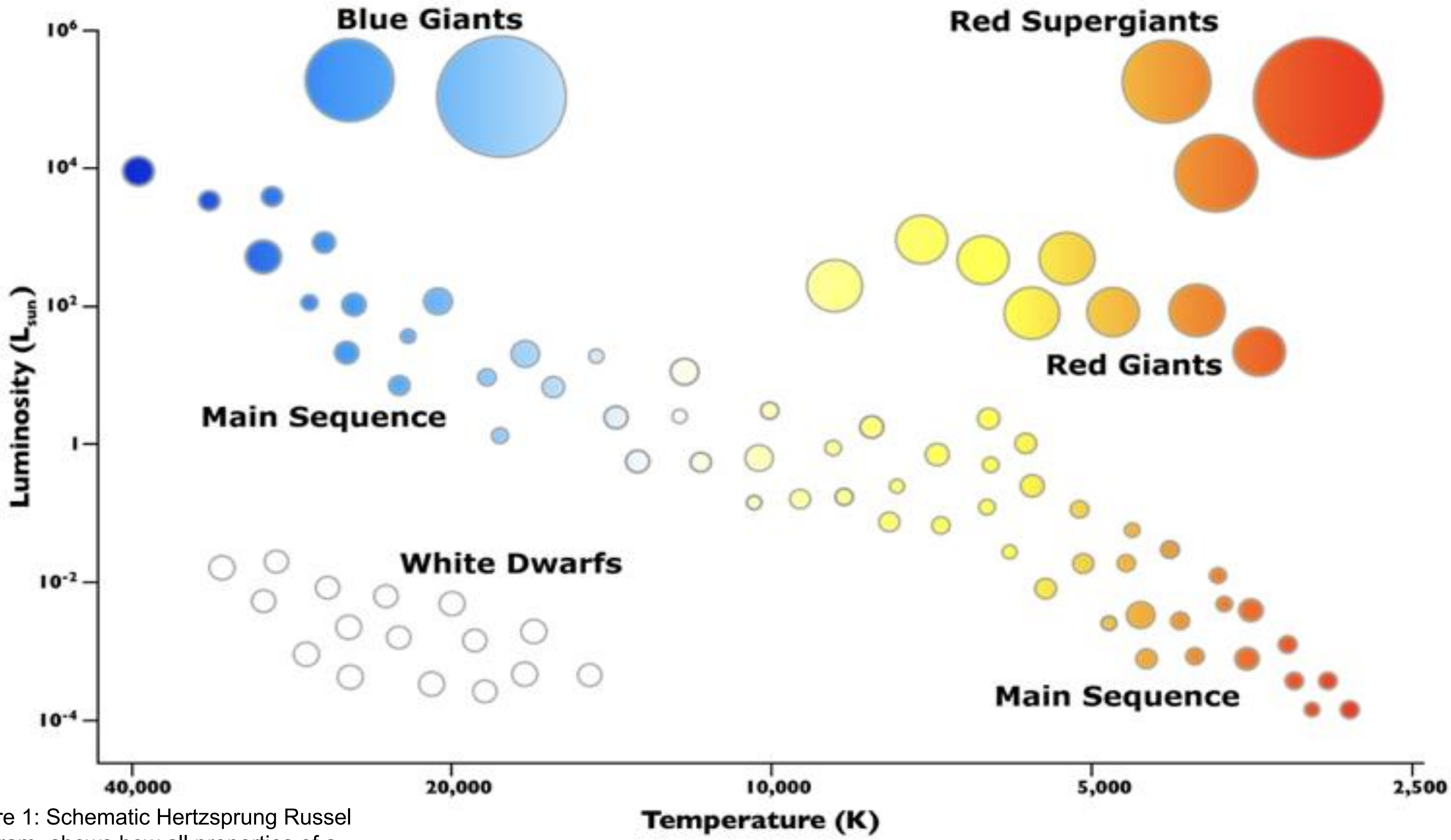
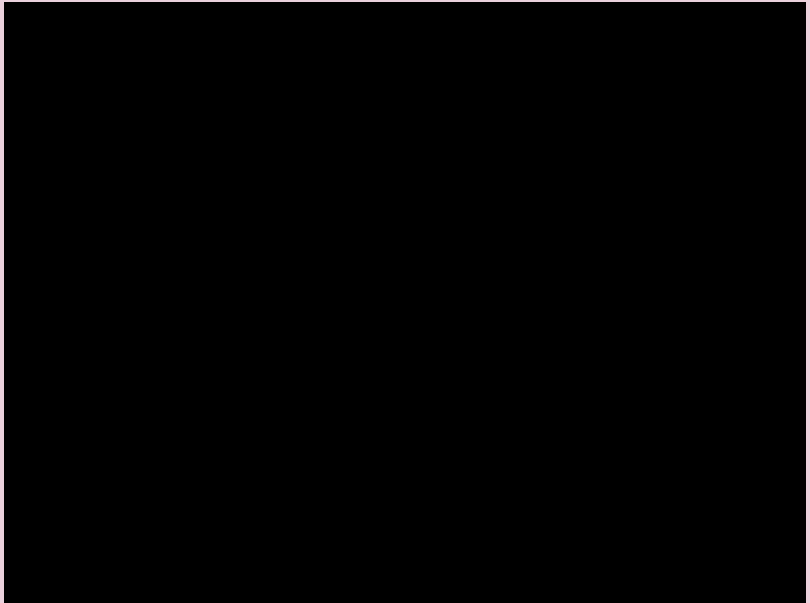


Figure 1: Schematic Hertzsprung Russel Diagram- shows how all properties of a star work together

Schematic Hertzsprung Russel Diagram

The graph on the previous slide is the Schematic Hertzsprung Russel Diagram. Watch the video down below to understand more about the graph, and how to use it.



Procedures

1. Gather a list of circumbinary star systems with an Earth-like planet in the habitable zone of the system.
2. Gather the necessary data about the stars to enter into the simulator:
   - Mass (M)
   - Temperature (K)
   - Luminosity (L)
   - Eccentricity
   - Semi-Major Axis (AU)
3. Access the simulator “Habitable Zones in Multiple Star Systems”

Procedures Continued

4. Enter the information about the stars and run the simulation.
5. Take note of what AU point the green habitable zone circle begins at and which point it ends at.
6. Analyze the habitable zone graph, as well as the data collected about the stars to run the simulation. The simulator variables include the distance of the habitable zone, the temperature, mass, and luminosity.
7. Conclude what type of stars are in the system using the Schematic Hertzsprung-Russel Diagram (Slide 8). Record in a data table.
8. Repeat this process with all the star systems.

Results - The Sun (Control)

Star Data and Information

The Sun

Temperature- 5.78×10^3K

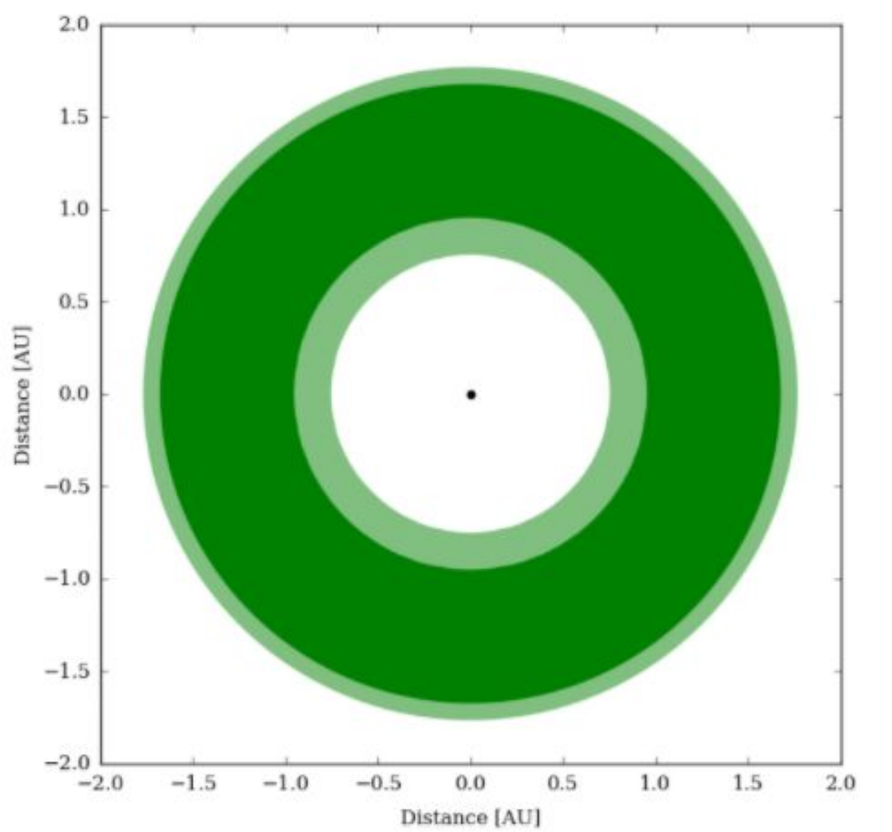
Luminosity- 1 L (1 = The Sun's luminosity)

Mass- 1 M (Solar Masses, 1 = Mass of the Sun)

Semi Major Axis- 1 AU

Eccentricity- 1

Results - The Sun (Control) Continued



Beginning Point- 0.75AU
Ending Point- 1.75 AU

The Sun- G class star (Yellow Dwarf)

Figure 2-Shows habitable zone of the Sun.

Results - Kepler 47 System

Star Data and Information

Kepler 47A

Temperature- 5.60×10^{3} K

Luminosity- 8.40×10^{1} L (1 = The Suns Luminosity)

Mass- 1.04×10^{0} M (Solar Masses, 1 = Mass of the Sun)

Kepler 47B

Temperature- 3.36×10^{3} K

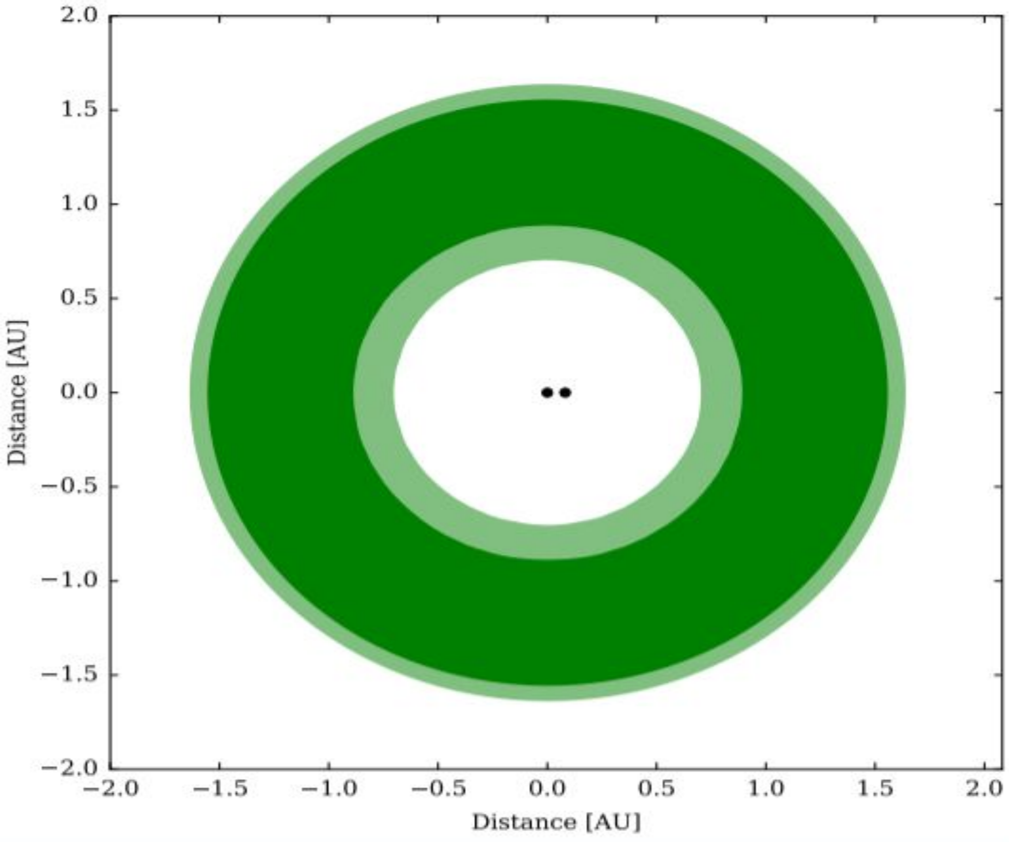
Luminosity- 1.40×10^{-2} L (1 = The Sun's Luminosity)

Mass- 3.62×10^{-1} M (Solar Masses, 1= Mass of the Sun)

Semi Major Axis- 8.36×10^{-2} AU

Eccentricity- 2.34×10^{-2}

Results - Kepler 47 Continued



Beginning Point- 0.75 AU
Ending Point- 1.75 AU

Kepler 47A- M class star (Red Dwarf)

Kepler 47B- G class star (Yellow Dwarf)

Figure 3- Shows habitable zone of Kepler 47 system.

Results - Kepler 16 System

Star Data and Information

Kepler 16A

Temperature- 4.45×10^{3} K

Luminosity- 1.48×10^{-1} L (1 = The Suns Luminosity)

Mass- 6.89×10^{-1} M (Solar Masses, 1 = Mass of the Sun)

Kepler 16B

Temperature- 3.31×10^{3} K

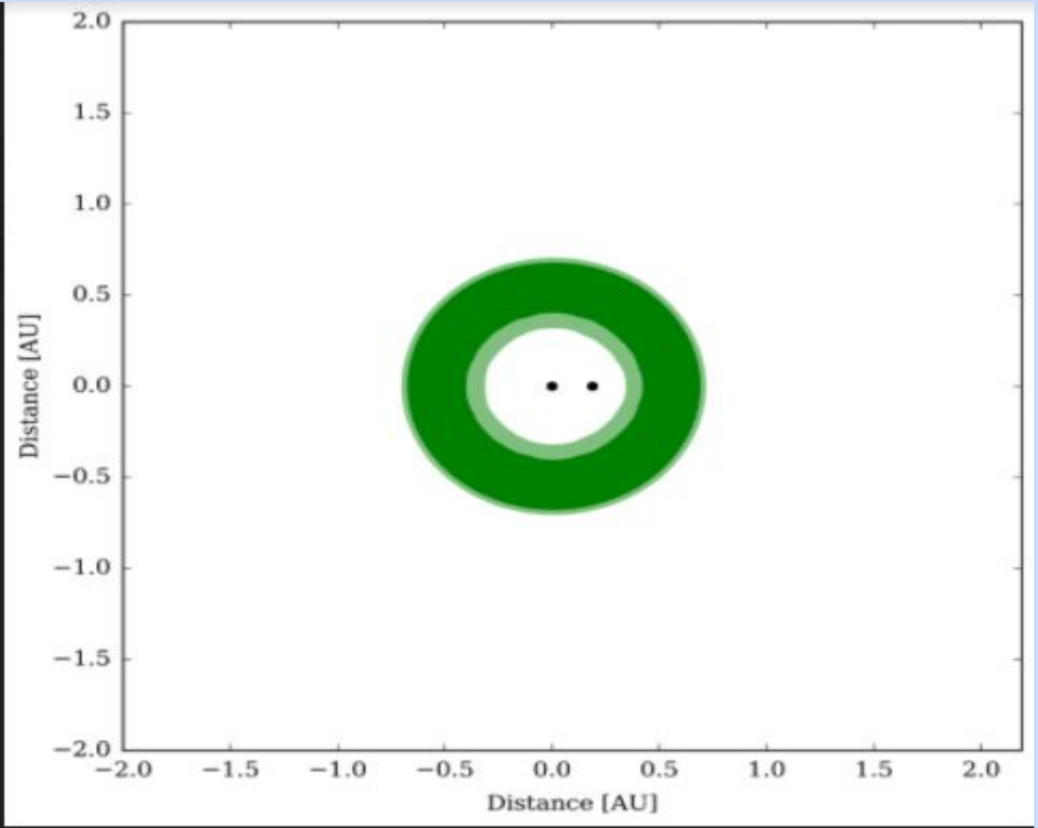
Luminosity- 5.70×10^{-3} L (1 = The Sun's Luminosity)

Mass- 2.03×10^{-1} M (Solar Masses, 1= Mass of the Sun)

Semi Major Axis- 2.24×10^{-1} AU

Eccentricity- 1.59×10^{-1}

Results- Kepler 16 System Continued



Beginning Point- 0.25 AU
Ending Point- 0.75 AU

Kepler 16A- M class star (Red Dwarf)

Kepler 16B- M class star (Red Dwarf)

Figure 4- Shows habitable zone of the Kepler 16 system.

Results - Kepler 38 System

Star Data and Information

Kepler 38A

Temperature- 5.64×10^{3} K

Luminosity- 8×10^{-1} L (1 = The Suns Luminosity)

Mass- 9.49×10^{-1} M (Solar Masses, 1 = Mass of the Sun)

Kepler 38B

Temperature- 5.64×10^{3} K

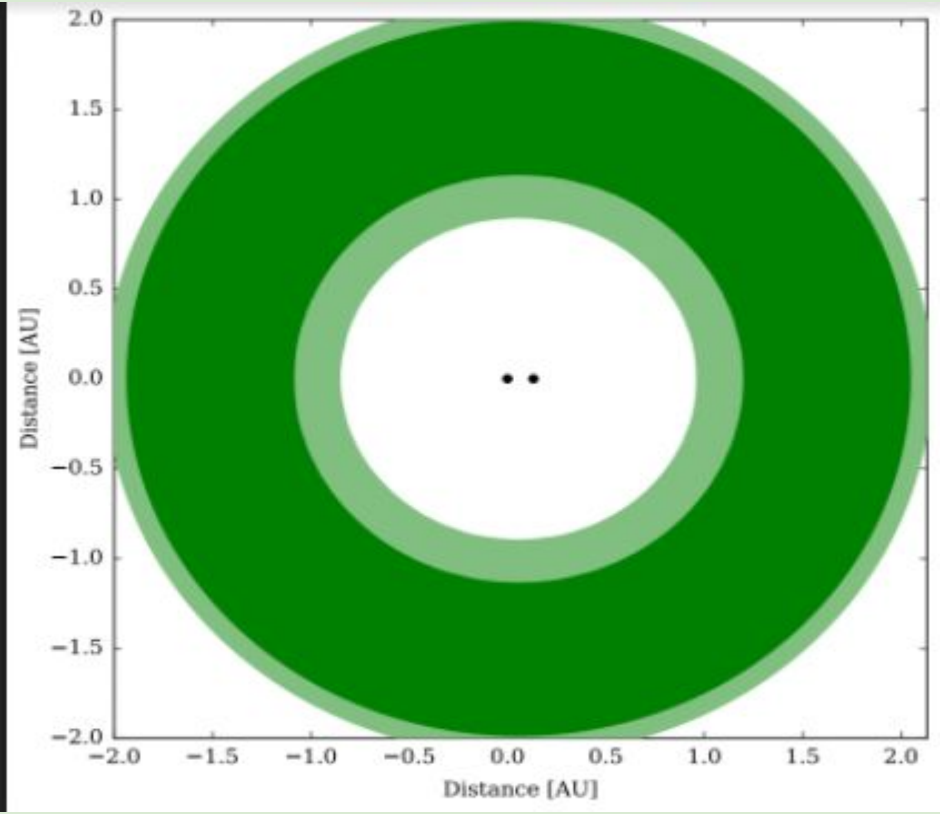
Luminosity- 6×10^{-1} L (1 = The Sun's Luminosity)

Mass- 2.49×10^{-1} M (Solar Masses, 1= Mass of the Sun)

Semi Major Axis- 1.46×10^{-1} AU

Eccentricity- 1.03×10^{-1}

Results - Kepler 38 System Continued



Beginning Point- 0.75AU
Ending Point- 2+ AU

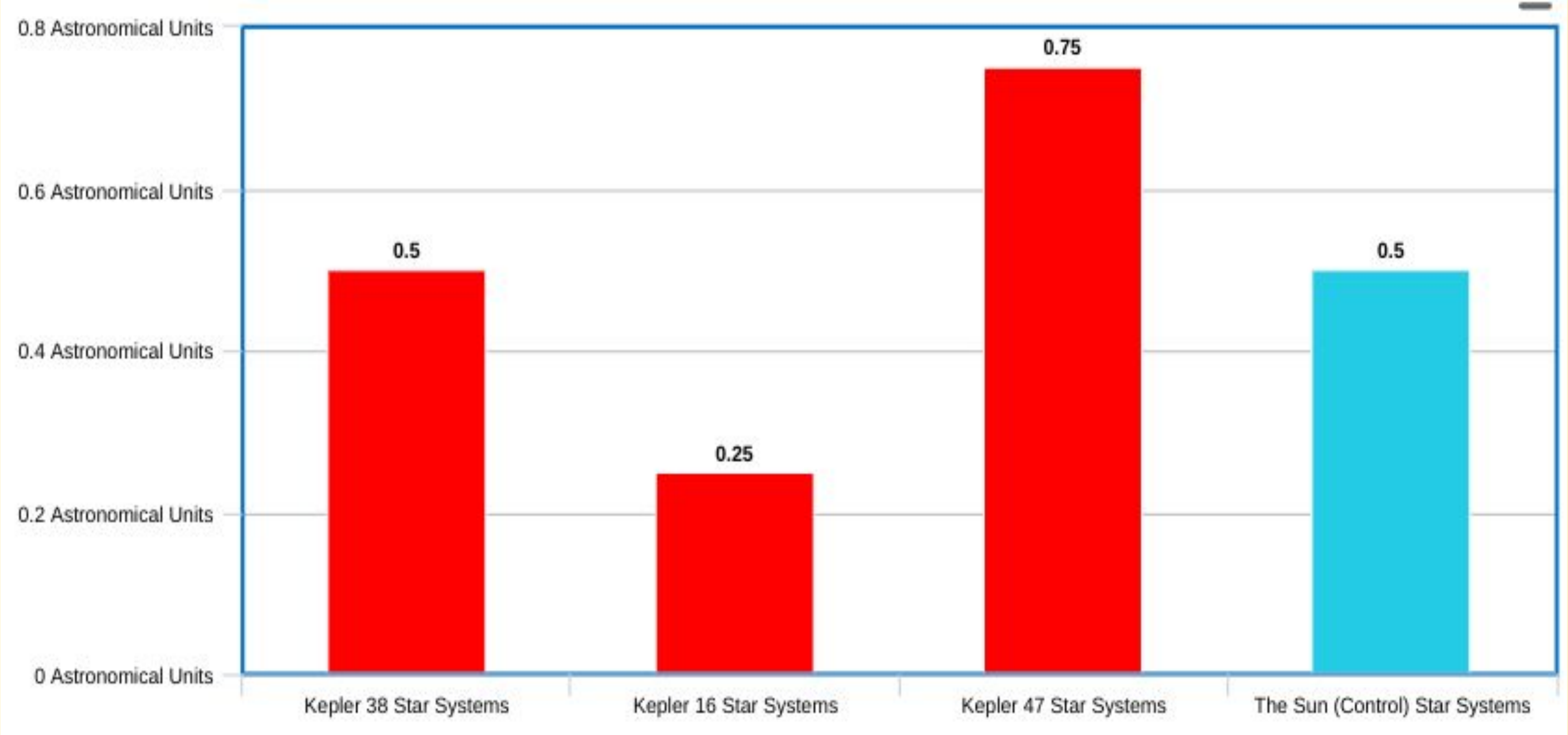
Kepler 38A- G class star (Yellow Dwarf)

Kepler 38B- M class star (Red Dwarf)

Figure 5- Shows habitable zone of the Kepler 38 system.

Starting Habitable Zone Points

Distance of habitable zone from stars (AU)

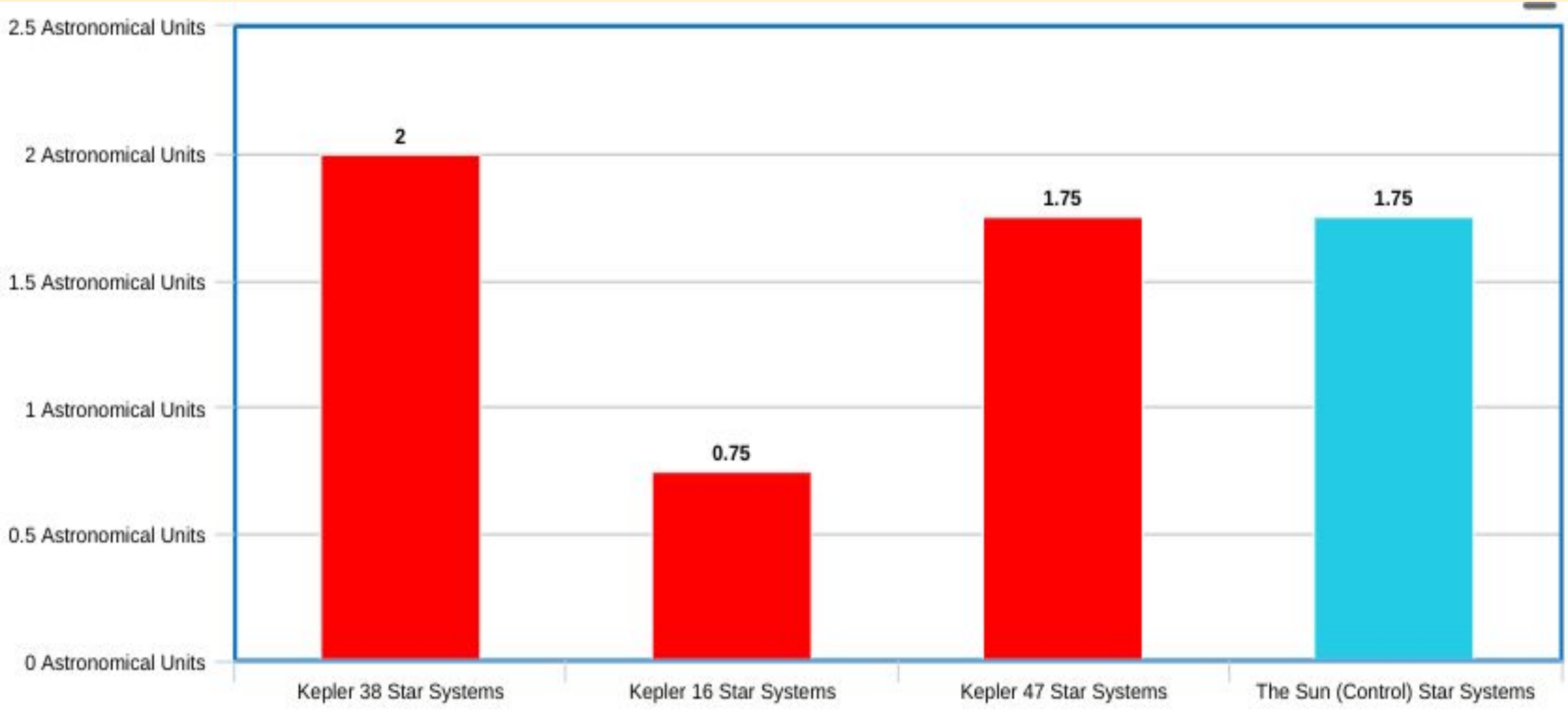


Star Systems

Figure 6- shows habitable zone starting points.

Ending Habitable Zone Points

Distance of habitable zone from stars (AU)

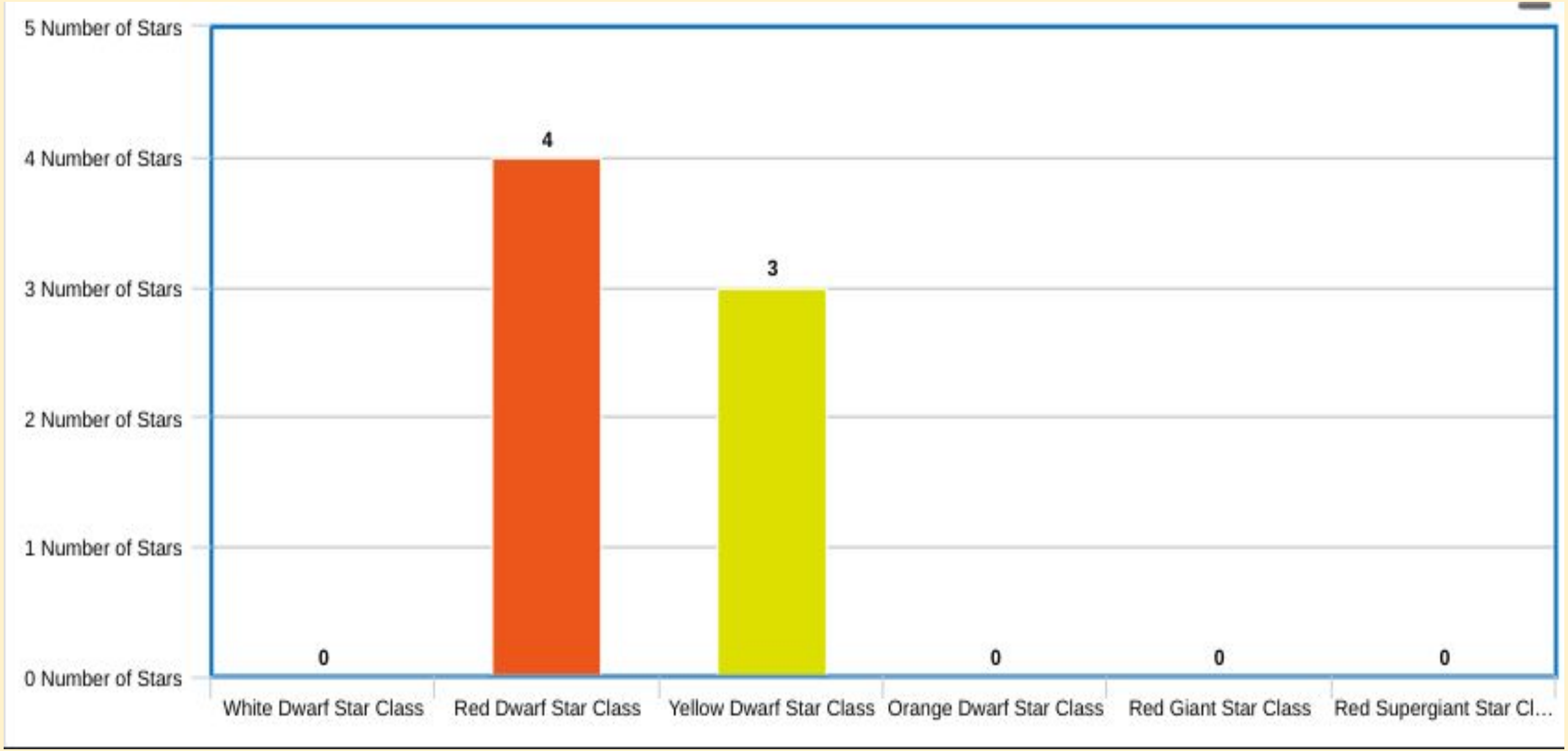


Star systems

Figure 7- Shows ending point of the habitable zone.

Average Star Stage

Number of stars



Star Classes

Figure 8- Shows the classes of the stars.

Conclusions

The hypothesis stated, if circumbinary systems are known to have habitable zones then binary systems that have simular qualities to the sun are more likely to have life-bound habitable zones. I predicted these planets will have a habitable zone of about 0.5 AU away from the star. I also hypothesized that 2 out of the 3 planets in the binary systems will have red dwarf stars as their host. The type of the star was found based on the data collected.

Conclusions - Continued

After analysis of the data, the hypothesis was accepted. The data collected shows that the average star in the systems are red dwarfs. My data also shows that the starting point of the habitable zone was 0.5 AU. The data correlates that the larger the stars are in a system, the habitable zones will be consequently larger and located further back in the zone. Subsequently, the smaller the stars, the closer the habitable zone is, and the habitable zone span is smaller.

Conclusions - Continued

The average star in the night sky is larger than the Sun. Over half the stars in the sky are supergiants and much larger than the sun. The data I collected helps to show that chances for life are very small and these conditions are very few and far between.

Red Dwarf General Information

Red dwarf stars are about the size of Jupiter. They are main sequence stars and eventually will turn into a red giant, then to a nebula, and finally into a white dwarf which is basically a dead star. Red Dwarfs are the most common type of star in the sjy and the most common star type to host planets. To the unaided eye they are extremely dim and are mainly just seen through telescopes. Red dwarfs are the M class star types and are relatively young compared to other stars. Proxima Centauri is an example of a Red Dwarf star.

Yellow Dwarf General Information

Yellow dwarf stars are larger than the average main sequence star or any red, yellow, or orange dwarf. Once there life spans are coming to a close, they will turn into a red giant then into a nebula and finally ending as a white dwarf. Yellow Dwarfs are common, but not the most common type of star. These stars are pretty easy to spot in the night sjy because of their yellow colors. Yellow Dwarfs are G class stars and are further along in their life spans than most main sequence stars. The one is one example of a yellow dwarf star.

Possible Experiental Errors

- One star had an estimated mass and another had an estimated temperature due to exact values not being available at this time.

Bibliography

Binary and Multiple Systems of Stars - https://www.sciencedirect.com/book/9780080169866/binary-and-multiple-systems-of-stars

An Introduction to Close Binary Stars - https://www.cambridge.org/core/books/an-introduction-to-close-binary-stars/29390D667C7BF531876FC96D5BCD1E17

Habitable Zones in Multiple Star Systems-

http://astro.twam.info/hz/

Acknowledgements

I’d like to thank everyone who has supported me and worked hard with me to make my project the one it is now. Specifically:

Mrs. Marks

Mr. Oste

Dr. Joshua Pepper (Lehigh University)

Dr. Robert Morehead (Penn State University)

Dr. Joseph Gerencher (Moravian College)

Lehigh Valley Amateur Astronomical Society

Thank you for viewing! If you have any questions or feedback please feel free to reach out to me!