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Stellar Visualizer: the Life of Stars

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ABSTRACT

Creating this simulation was to provide a general resource for learning about astronomy and stimulate an interest in astronomy. In the current situation, many schools do not teach or provide a means for studying astronomy, thus publishing such a simulation would prove useful as another way of learning the life of stars. When first trying to tackle the problem I had to ensure that the sources that I visited were reliable, thus I looked for ones written by trusted professors and universities, or those published by the government, namely NASA. As for the pictures I had to try my best to find ones that represent various stellar objects. Nearly all the pictures I found were models of stellar objects, as there aren't real pictures that had a clear enough resolution for use. Finally, the actual programming was done through examining each component of the simulation and coding block by block with a language called p5.js.

Keywords: (none)

1. INTRODUCTION

1.1 Motivation

With the ever growing needs of humanity, the Earth alone cannot account for all the resources and energy requirements that we need to survive without drastically changing our way of life. Therefore, as many contemporary scientists suggest, we must explore the world beyond the boundaries of our planet. However, at our current status quo, standardized education does not put sufficient emphasis on the importance of this field of study. As a person with a passion towards astronomy and astrophysics, I have learned most of my knowledge from the internet, with quite limiting resources. Therefore, to encourage a passion for astronomy and astrophysics which will most definitely be a vital part of our future, I was motivated to create an interactive simulation of the life of a star, which I believe, is a key component of astronomy. Through this simulation, I hope to educate people about the world outside our blue planet and encourage more people to take interest in outer space.

1.2 Design of the Research

First I had to research the different stages that a star can possibly go through, such as a nebula, a main sequence star, a red giant etc. I found that the mass of a star dictated most other factors of a star such as the temperature, brightness and size. Hence, I set the mass of the star as a variable that the user can change. This inputted mass will then be processed to output the size, temperature and brightness according to the CSV file above. Afterwards, I used high quality images taken by the NASA Hubble Space Telescope and other observing facilities to visually portray the stages of the star. Using all this data, I used a language called p5.js, a javascript based programming language to compose an interactive program. In addition to animating the images of the star according to the data inputted by the user, I also added a slider at the bottom that represents the timeline of the star. This slider can be controlled by the user and will allow them to jump from stage to stage in a single click. The authentic code for the program can be accessed here: https://preview.p5js.org/blinkingstar/present/gbVEsvFPE.

2. BACKGROUND KNOWLEDGE

The life of a star starts with a Nebula. A Nebula is a cloud of dust and gas, composed mostly of hydrogen and helium. These particles are brought together into spherical shape from gravity, eventually to the point where nuclear fusion occurs in the interior. This nuclear fusion produces an immense amount of energy; enough energy to push back against gravity. At this point, contraction of the star stops and delicate equilibrium is reached between the outward pressure of nuclear fusion and gravity. A star is now born. [1]

From this point, there are several different paths a star can take depending on its initial mass. At the lowest end of the mass spectrum, a cluster of mass less than (number) is considered a brown dwarf; a failed star. A brown dwarf does not carry out nuclear fusion which is responsible for the luminous quality of stars. Therefore it is incredibly hard to detect. A brown dwarf ranges from 13 to 80 times the size of Jupiter. It isn't clear as to what happens to a brown dwarf as it ends its life. Many scientists believe that it would simply fade away and disintegrate into its fundamental components (hydrogen and helium). [2]

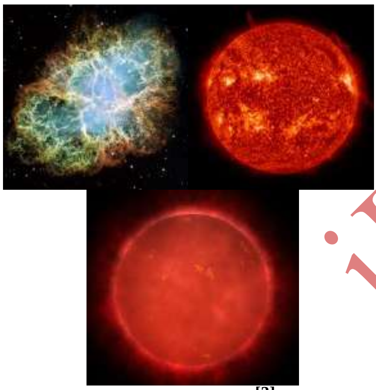


Figure 1: An image of nebula[3], main sequence star[4], red dwarfs[5]

From an initial mass of more than 0.08 solar masses, we get the first "successful" star with the lowest mass and luminosity. These stars can be classified as main sequence stars In these mass ranges, a Type-M star is formed, more commonly referred to as a red dwarf. These dimly glowing objects are the most prevalent in our universe, estimated to be at least 100 billion red dwarfs in our milky way. A red dwarf produces a red colour as it burns through its hydrogen. Exclusively for red dwarfs, the products of nuclear fusion in the core of the star, rise up to the surface of the star, pushing other non-fused hydrogen molecules down to the core. This convective movement of the molecules allows red dwarfs to utilize nearly all of its available hydrogen, delaying the exhaustion of fuel, which is the underlying reason to the extensive lifetime of red dwarfs. In fact, red dwarfs with the lowest mass have an estimated lifespan of 10 trillion years, roughly a thousand times the age of the entire universe. A red dwarf isn't, however, massive enough to enter a giant phase (which will be discussed later in further detail). [6]

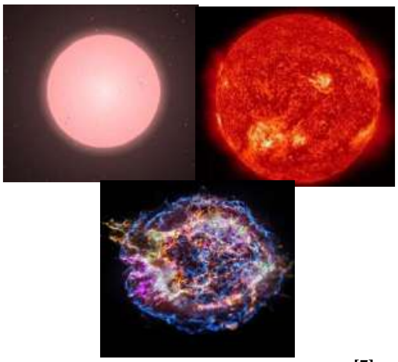
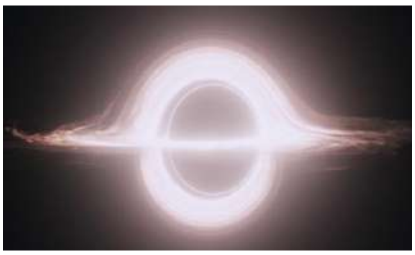


Figure 2: An image of supergiants[7], red giants[8], supernova[9]

Formations of solar mass 0.1 to 150 lead to a typical main sequence main sequence star such as our own star. According to the mass of each of these celestial bodies, its luminosity, temperature, lifespan and colour can vary. At the very top, with the highest mass, there are Type O stars (blue), then Type B stars (blue), Type A stars (Blue-white or white), Type F stars (white), Type G stars (yellow-white), and Type K stars(orange). These stars fuse hydrogen in its core, converting , and they do so for millions, or in some cases, billions of years. As the star begins to fuse its last hydrogen molecules into helium and even helium into oxygen or carbon, the energy produced by nuclear fusion dwindles, causing the fragile equilibrium to become unstable. The star begins to pulsate, in other words, goes through stellar pulsation. [10]



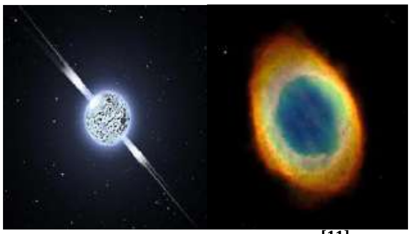


Figure 3: An image of black holes[11], neutron star[12], planetary nebula[13]

Once the core of the star becomes predominantly composed of oxygen and carbon, the star shrinks rapidly, becoming bluer and hotter. At this point, there is close to no fuel left to burn, causing the core to collapse the outer layer to expand again. This expansion doesn't stop until the outer layers are completely ejected, to form a planetary nebula. In the core of this nebula is a white dwarf star, the former core of the dead star. From this point forth, the white dwarf would lose its heat only through radiation as there are no molecules in a vacuum where the star can transfer its heat to. As this process is extremely inefficient, it can take up to 20 billion years. After that, the star would simply fade away, turning into a black dwarf. Since the universe is only 14 billion years old, it is improbable that black dwarfs exist, making them theoretical objects. Even if they do exist, they would be incredibly hard to spot due to their dark nature. However, it is speculated that black dwarfs are one of the coldest objects in the universe, being 2 - 3K (0K is the lowest temperature possible). [14]

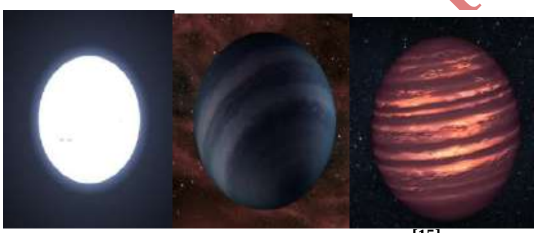


Figure 4: An image of white dwarfs[15], black dwarfs[16], brown dwarfs[17]

For stars of initial masses more than 8 solar masses, however, end differently. These stars have enough mass to fuse oxygen and carbon into neon, then silicone, then iron, at which point nuclear fusion can no longer occur (iron is too stable). Gravity wins over and collapses down onto the core with incredible force. At this stage, the electrons and protons in the atoms of the core fuse into neutrons which then get further compressed into the size of atomic nuclei. The implosion of the star is then bounced back by the iron core, creating a supernova that can outshine entire galaxies. Supernova explosions are the origin of many of the heavier elements (elements after iron) in our universe. In the center of the supernova is a neutron star, a star made up of tightly packed iron nuclei. [18]

3. IMPLEMENTATION

The program was created using a language called p5.js. P5.js is a modification of a language called processing, created into a javascript version. It is suitable for portraying basic graphics and building apps. The demo can be accessed here:https://preview.p5js.org/blinkingstar/present/gbVEsvFPE

Figure 5: Appearance of the Main page

The whole simulation is divided into three main sectors: the home screen, the transitions, and the main simulation. To represent the current status of the simulation, a variable called "currentStatus" was set.

```
const MAIN = 1
const MAIN_FADING = 2;
const SIMULATION = 3;

var currentStatus = MAIN;

functiondraw() {
 if (currentStatus == MAIN || currentStatus == MAIN_FADING) {
  drawMain();
 } elseif (currentStatus == SIMULATION) {
  drawSimulation();
 }
}
```

Figure6: The structure of the program

```
functionpreload() {
  for (var i=0; i<18; i++) {
    imgs[i] = loadImage("./pictures/Star_"+str(i+1)+".jpg");
  }

  for (var i=0; i<massList.length; i++) {
    tables[i] =
loadTable("./csv/star_"+str(massList[i])+"_solar_mass.csv");
  }
}
```

Figure7: Calling the images and information from the CSV file

All the data on the mass, size, luminosity and temperature have been derived from a CSV file which is preloaded as soon as the simulation starts. A CSV file, also known as comma separated value, is a common file type used for storing mass amounts of data.

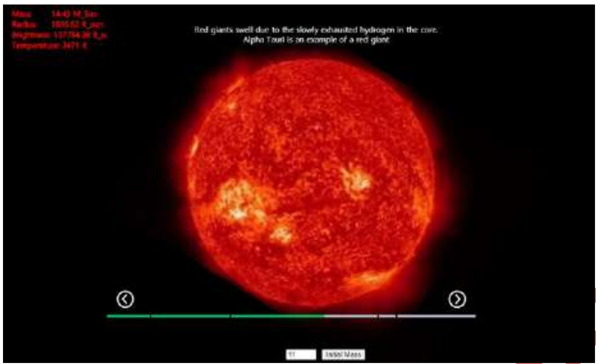


Figure 8: Appearance of the simulation

```
functiondrawSimulation() {
  blendMode(BLEND);
  imageMode(CENTER);
  background(0);

  if (initTimeLine == 1) {
    initTimeLine = 0;
    drawInput();
    updateScenario();
  }
  button.mousePressed(updateScenario);

  drawDiagram();
  drawDashBoard();
  drawTextBox();
  drawTimeLine();
}
```

Figure9: Structure of the simulation code

Within the simulation sector, there are four components included. 1. “drawDiagram()” which shows the actual image of the stellar object, 2. drawDashBoard() which displays all the information (mass, size, luminosity, temperature), 3. drawTextBox() which displays a simple explanation of the image displayed by “drawDiagram()”, and finally 4. drawTimeLine() which shows the timeline and progress in the star cycle.

```
functiondrawDiagram() {
  noFill();
  stroke('black');
  strokeWeight(5);

  push();
  translate(width/2, height/2);
  rotation += 0.001;
  rotate(rotation);
  image(imgs[img], 0, 0);
  rectMode(CENTER);
  rect(0, 0, imgs[img].width, imgs[img].height);
  pop();
}
```

Figure10: Structure of drawDiagram()

To make the simulation more realistic, the drawDiagram() function includes a code to rotate the image of the star. One problem that I’ve encountered was that there seemed to be a blue border line around each image when I first uploaded it. To amend this issue, a rectangular black frame was superimposed to cover up the borderline.

```
classScenario {
  constructor(ts, pn, tc) {
    this.timeSegments = ts;
    this.pictureNum = pn;
  }
}

var scenarioList = [
  new Scenario([350, 3000], [0, 16]),
  new Scenario([350, 1500, 2900, 3000], [0, 7, 14, 15]),
  new Scenario([350, 1000, 2200, 2350, 2900, 3000], [0, 6, 8, 13, 14,
15]),
  new Scenario([350, 1000, 2200, 2350, 2900, 3000], [0, 5, 8, 13, 14,
15]),
  new Scenario([350, 1000, 2200, 2350, 2900, 3000], [0, 4, 8, 13, 14,
15]),
  new Scenario([350, 1000, 2200, 2350, 2900, 3000], [0, 3, 8, 13, 14,
15]),
  new Scenario([350, 1000, 2200, 2350, 2900, 3000], [0, 2, 8, 13, 14,
15]),
  new Scenario([350, 1000, 2200, 2350, 3000], [0, 1, 8, 10, 12]),
  new Scenario([350, 1000, 2200, 2350, 3000], [0, 1, 8, 10, 11]),
]
```

Figure11: Code structure for the differentscenarios

Since the initial mass is the ultimate determinant of the outcome of the star, 9 scenarios were created to represent the different outcomes of the star. Using a class called “Scenario”, the information was translated onto the program, storing important data such as when the simulation should display what image.

4. CONCLUSION

Creating a simulation about something that I took profound interest in was a meaningful experience. A project of a magnitude so large relative to other personal endeavors was challenging at the very least and it was clear much organization and planning was needed before any coding was done (It was later evident how pivotal this was since without it, there would have been a significant amount of more time wasted from trying to debug a messy block of code). There were many obstacles faced, mainly due to inexperience, and there were ideas that had to be dropped as its addition would have taken too much time. Changes and improvements will most likely come in the near future, especially in the design aspect such as the graphics and animation of the simulation. All in all though, the end result is a success and should there be another opportunity for such a project, it would be tackled with much more proficiency gained from experience. It would be a delight to watch students use the simulation as a learning resource, which was the ultimate goal.

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