How Astronomers Measure Distance: Cepheid Variables

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ABSTRACT

In order to map our universe, astronomers must be able to measure distances accurately. In 1912, a study by Henrietta Leavitt on several thousand stars was published that documented the direct relationship between the known brightness of the stars with the period of time during which their brightnesses regularly fluctuated between two extreme values. This class of stars came to be known as classical Cepheid variables, and by comparing the apparent brightness measured from earth with the known actual brightness of the star, the distance to the star could be calculated with previously unmatched accuracy. Using existing tabulated star luminosity data, we seek to develop a computer program to automate these distance calculations.

INTRODUCTION

Cepheid Uses / History
- Measuring universal distance
- Discovered by Henrietta Leavitt

How Cepheids Work
- Cepheid's are related by their period and luminosity
  - Maximum change in brightness over a certain time
  - Period-Luminosity Relationship: the longer the period the more luminous the star
- Outer layers expand/contract in a cycle that changes the star's luminosity

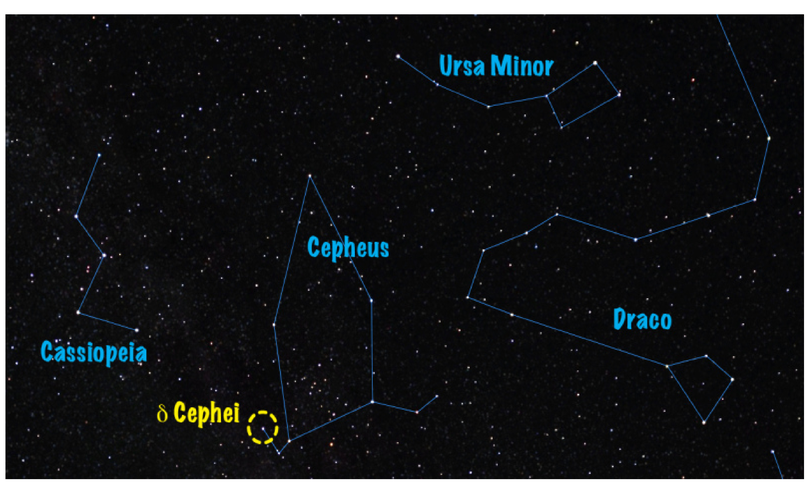

Figure 1. Delta Cephei, a famous Cepheid Variable, can be found in relation to other known constellations

METHODS / PROGRAMMING

```
//calculates for Absolute Magnitude
public static double calculateM(double[][] database, int line){
    database[M][line] = database[x][line] + database[y][line]*Math.log10(database[P][line])
     + database[z][line]*database[A][line];
    return database[M][line];
}
```

- Calculates the absolute magnitude of the Cepheid given in the database

```
public static double calculateDistance(double[][] database, int line) {
    database[u][line] = mOb - M;
    database[d][line] = Math.pow(10, (u/5+1));
    return database[d][line];
}
```

- Measures distance in parsecs using absolute and apparent magnitude

Why a Program:
- Automates the distance calculations
- Allows for the data to be found in a large database
  - Useful for data analysis of Cepheids
    - Could be used for comparing distance calculations in different databases in future work

SAMPLE CALCULATION

- Equations Used:
  - Mv = - 1.371 - 2.986 * log(P)
  - d = 10^(u/5+1)
  - u = m - Mv
- Sample Calculation for One Star:

STAR: RT Auriga

Mv = -1.371 - 2.986*log(3.728190)
Mv = - 3.077493139

u = 5.446 - (-3.077493139)
u = 8.523493139

d = 10^((8.523493139/5) + 1)
d ≈ 507 parsecs

Database Value: 426 parsecs
% Error = $\frac{507-426}{426} * 100 = 19\%$

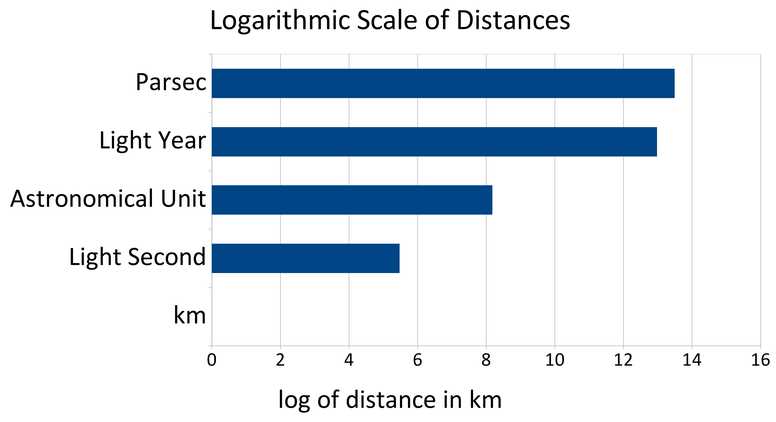

Figure 2. A relative scale of distances to showcase how large a parsec is

CONCLUSIONS

Issues Found in Research
- Some period-luminosity equations used amplitude and others did not
- Different equations use different constants

Drawbacks to Cepheid Variables
- Not actually very bright; they can not be seen from far away or when obstructed
- Speed of light means the further away you see, the further back in time you see

Current Uses
- Stellar evolution

- Our aim was to help collegiate-level students understand Cepheid Variables

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