Lab 4 Light Curve of a Variable Star

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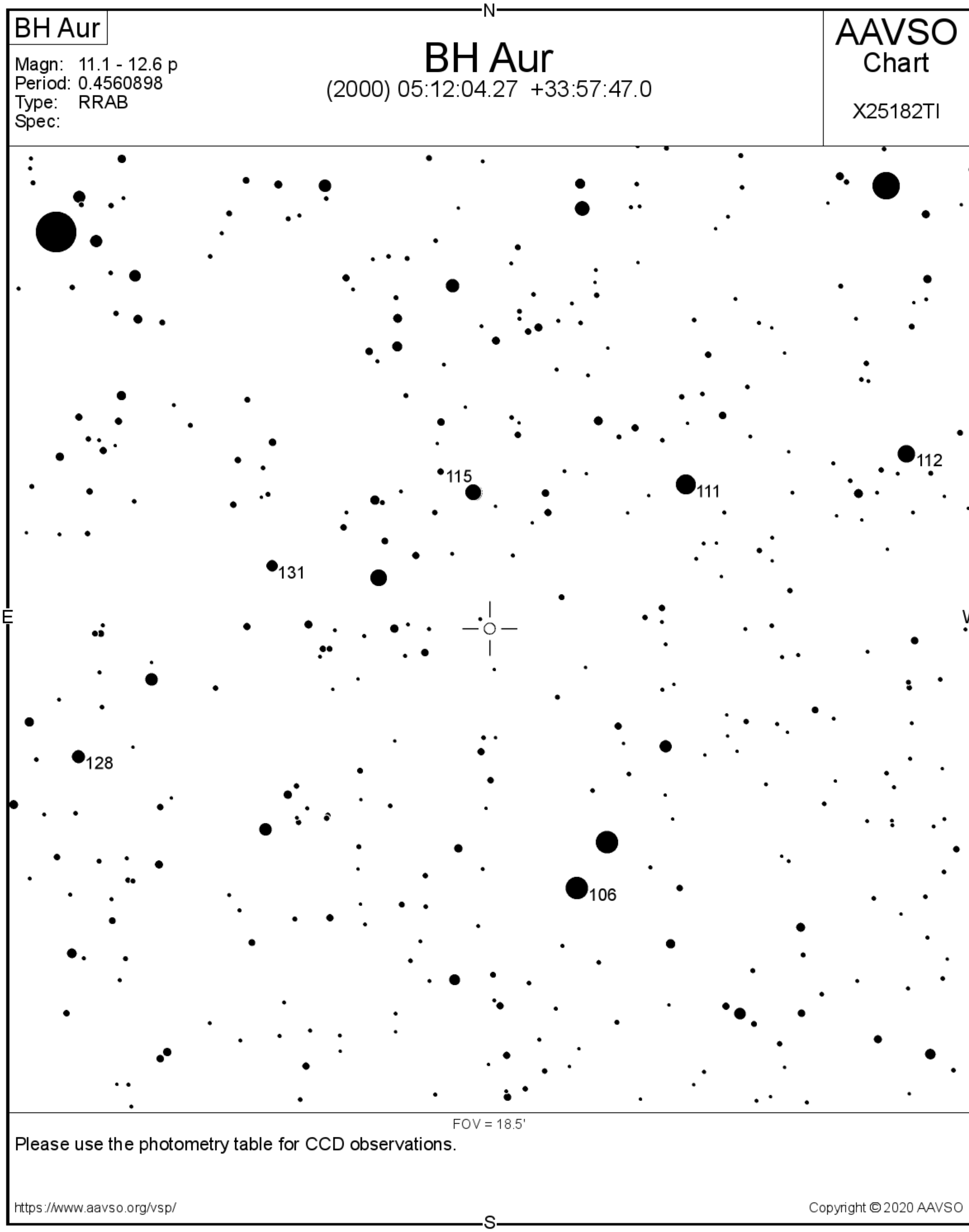
Abstract

A variable star was observed and a light curve created using aperature and differential photometry. Through successive observations the light curves were correlated and the period calculated. This value was in good agreeement with the published values. Through a period/magnitude relationship for RR Lyrae stars the absolute magnitude was calculated. By comparing this value to the apparent magnitude the distance was calculated. These values were close to the published values considering a number of assumptions that needed to be made with regards to the mass and metalicity of the variable star.

BH Auriga

BH Auriga is a RRAB variable star with a period of 0.4560898 days. It.s magnitude varies from 11.1 to 12.6. The star was selected based on nightly recommendations from AAVSO. It was selected for its visibility, its large change, its short period and its proximity to comparison stars (Finder chart and table shown below).


N
BH Aur
Magn: 11.1 - 12.6 p
Period: 0.4560898
Type: RRAB
Spec:
BH Aur
(2000) 05:12:04.27 +33:57:47.0
AAVSO
Chart
X25182TI
E
W
115
111
112
131
128
106
FOV = 18.5'
Please use the photometry table for CCD observations.
https://www.aavso.org/vsp/
Copyright © 2020 AAVSO
S

AUID	RA	Dec	Label	V	B-V	Comments
000-BBJ-026	05:11:56.24 [77.98432922°]	33:52:49.0 [33.88027954°]	**106**	10.561 (0.018)[18]	0.609 (0.028)	
000-BBJ-024	05:11:46.14 [77.94225311°]	34:00:32.6 [34.00905609°]	**111**	11.105 (0.013)[18]	0.440 (0.025)	
000-BBJ-016	05:11:25.76 [77.85733032°]	34:01:07.6 [34.01877975°]	**112**	11.233 (0.018)[18]	0.378 (0.030)	
000-BBJ-029	05:12:05.79 [78.02412415°]	34:00:23.4 [34.00650024°]	**115**	11.502 (0.012)[18]	0.444 (0.022)	
000-BBJ-035	05:12:42.20 [78.17583466°]	33:55:20.0 [33.92222214°]	**128**	12.795 (0.017)[18]	1.037 (0.043)	
000-BBJ-034	05:12:24.40 [78.10166931°]	33:58:59.1 [33.98308563°]	**131**	13.066 (0.015)[18]	0.541 (0.039)	

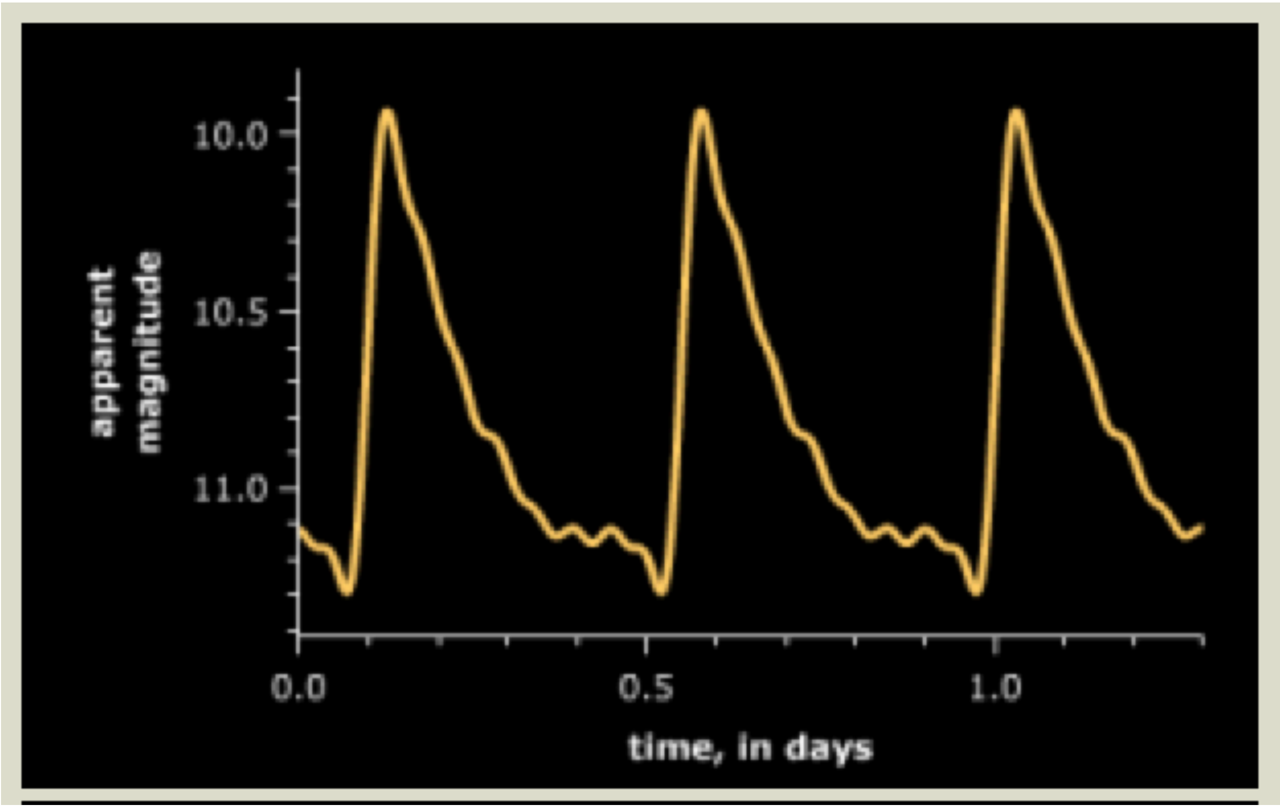
- **AUID** is the AAVSO Unique Identifier for the star. When reporting a problem, please include this AUID.
- Coordinates are in J2000 sexagesimal format, followed by decimal degrees
- Search for variable stars in this field via VSX
- **Label** is that star's label when plotted on an AAVSO chart, usually (but not always) its V magnitude rounded to the nearest tenth.

Source Reference Table

Footnote	Source	Footnote	Source	Footnote	Source
1	Tycho-2	17	ASAS	33	SRO50
2	GSC 1.2	18	SRO	34	K35

RRAB variables have a characteristic rapid rise up to a peak and a slower fall down to their minimum. This makes it an attractive candidate to observe since you can capture both the minimum and the maximum in the same observing session.

The mechanism behind the pulsations in RR Lyrae stars is related to partial second ionization of helium. This makes the atmosphere unstable against pulsations as the opacity increases with temperature. As a layer of the atmosphere moves inward, it becomes denser and more opaque, checking the heat flow. Heat increases and temperature builds causing a build-up of pressure that pushes the layer outward again in a cyclic manner. (Maeder, 2009)

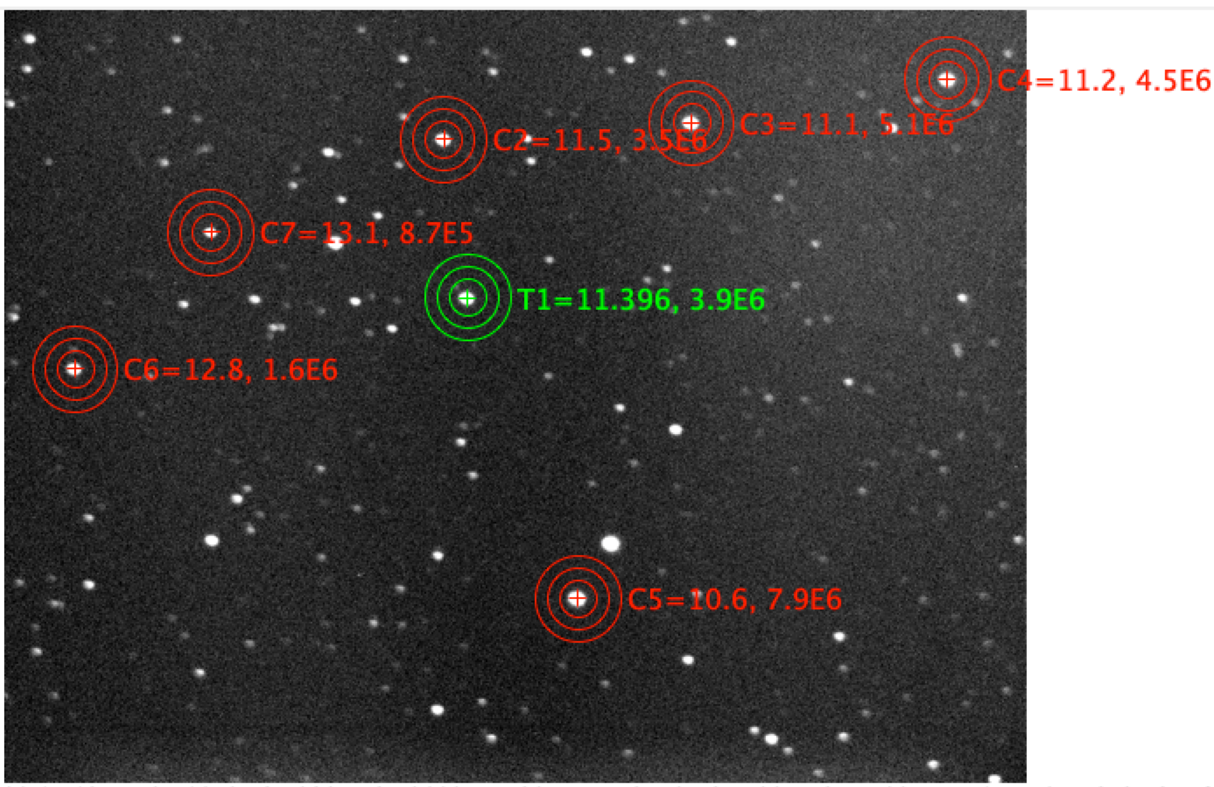


A light curve was constructed from observations taken over three nights, generally two minute exposures on a five minute cadence using 2x2 binning and a clear filter. The observations were made on 03/03/2020, 03/04/2020 and 03/08/2020 with the UWM 14" telescope and CCD camera. The time of the maximum from each night was found from Stellarium and verified with AAVSO data.

AstroImageJ (AIJ) was used extensively to calibrate the images with bias, dark and flat field images. Astrometry.net was used to obtain astrometric solutions for each image. AIJ's Multi-Aperature functionality was used to select stars to analyze and compare. (Collins, 2017)

The output file was then read into Phython and the data plotted in a light curve. The data from each night was translated according to the given period to construct a relatively complete light curve.

The minimum magnitudes where found to be near 12.07 and the maximums near 11.2. The period was calculated and found to be in close agreement with the published values found in Simbad. The period found was used to calculate the magnitude of the star through a period-magnitude relationship. This was then used to find the distance of the star. (Caputo, 1997)



Light Curve

In [1]:

```
from astropy.io import fits
from os import walk
from matplotlib import pyplot as plt

import numpy as np
from scipy import stats

```

In [2]:

```
JD_03032020_Max = 2458912.72745 # Max at 05:27.32 UTC 03-04-2020 OR

# Data covers from .6 to .727 or .127 prior to peak

JD_03042020_Max = 2458913.63963 # Max at 03:21:04 UTC 03-05-2020 OR

# Data covers from .64 to .80 or .16 past the peak

JD_03092020_Max = 2458913.74444 # Max at 05:52:00 UTC 03-05-2020 OR

# Data covers from .53 to .74 or .21 prior to the peak
```

In [11]:

```
data = np.genfromtxt(fname="50Measurements.tsv", delimiter="\t", ski
print("Data shows",data.shape[0],"observations in this lightcurve.")
print("The minimum magnitude was %0.4f" % max(lata[:50,21]),"and the
print("The mean magnitude was %0.4f" % np.mean(lata[:50,21]),"and th
```

```
Data shows 51 observations in this lightcurve.
The minimum magnitude was 12.0782 and the maximum was 11.2128
The mean magnitude was 11.6820 and the median was 11.6716
```

In [13]:

```
lata = np.genfromtxt(fname="90Measurements.tsv", delimiter="\t", ski
print("Data shows",lata.shape[0],"observations in this lightcurve.")
print("The minimum magnitude was %0.4f" % max(lata[:,21]),"and the m
print("The mean magnitude was %0.4f" % np.mean(lata[:,21]),"and the 
```

```
Data shows 90 observations in this lightcurve.
The minimum magnitude was 12.0782 and the maximum was 11.2505
The mean magnitude was 11.6394 and the median was 11.6122
```

In [14]:
```
lsta = np.genfromtxt(fname="48Measurements.tsv", delimiter="\t", ski
print("Data shows",lsta.shape[0],"observations in this lightcurve.")
print("The minimum magnitude was %0.4f" % max(lsta[:50,21]),"and the
print("(Note: not near peak time.)")
print("The mean magnitude was %0.4f" % np.mean(lsta[:50,21]),"and th
```

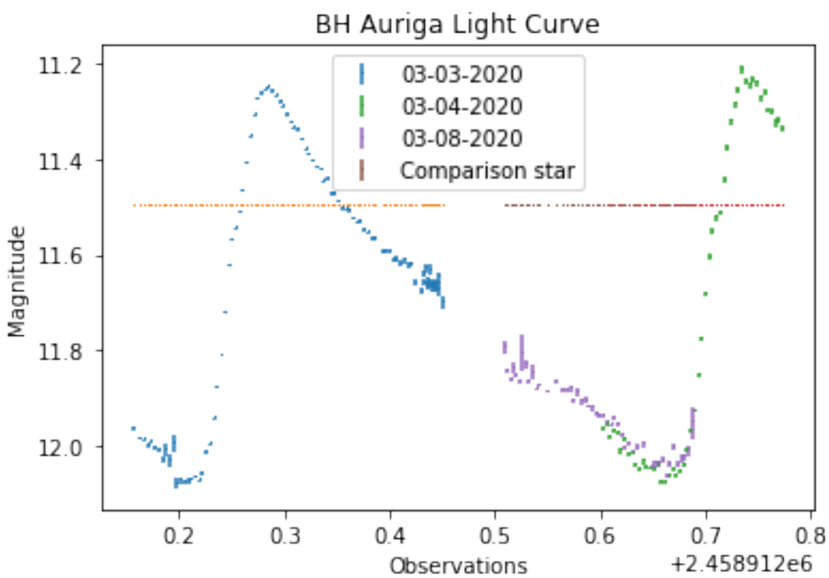
```
Data shows 48 observations in this lightcurve.
The minimum magnitude was 12.0621 and the maximum was 11.7932
(Note: not near peak time.)
The mean magnitude was 11.9352 and the median was 11.9350
```

In [16]:
```
MeanMag = (data.shape[0]*np.mean(data[:50,21])+lata.shape[0]*np.mean
MedianMag = (data.shape[0]*np.median(data[:50,21])+lata.shape[0]*np.
print("The overall mean magnitude was %0.4f" % MeanMag,"and the over

```

```
The overall mean magnitude was 11.7360 and the overall median was 11.7
828
```

In [17]:
```
Lray = (lata[:,5]-(.45609*3))

C0Mag = (lata[:,21])
C0Erray = (lata[:,17])
plt.errorbar(Lray,C0Mag,yerr=C0Erray, fmt=',', label = '03-03-2020')

C1Mag = (lata[:,27])
C1Erray = (lata[:,18])
plt.errorbar(Lray,C1Mag,yerr=C1Erray, fmt=',')

Xray = (data[:50,5])
C2Array = (data[:50,21])
#print(Xray)
#print(C2Array)
C2Erray = (data[:50,17])
plt.errorbar(Xray,C2Array,yerr=C2Erray, fmt=',', label = '03-04-2020


C3Array = (data[:50,27])
C3Erray = (data[:50,18])
plt.errorbar(Xray,C3Array,yerr=C3Erray, fmt=',')


#lray = (lsta[:50,5])
lray = (lsta[:,5]-(.45609*11))
C4Array = (lsta[:50,21])
#print(Xray)
#print(C2Array)
C4Erray = (lsta[:50,17])
plt.errorbar(lray,C4Array,yerr=C4Erray, fmt=',', label = '03-08-2020
```

```
C5Array = (lsta[:50,27])
C5Erray = (lsta[:50,18])
plt.errorbar(lray,C5Array,yerr=C5Erray, fmt=',', label = 'Comparison


#print(YErrArray, XErrArray),
plt.gca().invert_yaxis()
#plt.xlim(-1,2)
#plt.ylim(18,9)
plt.title("BH Auriga Light Curve")
plt.xlabel("Observations")
plt.ylabel("Magnitude")
plt.legend()
plt.show()
```



Period Calculation

In [18]:

```
# Minimums were too noisy, switched to time of rise (below 12 mag)
RysATime = 2458912.682659 #MinATime = 2458912.661705
RysBTime = 2458913.594116 #MinBTime = 2458913.566211
RysCTime = 2458917.700778 #MinCTime = 2458917.679843
TestPeriod = RysBTime - RysATime
TestIntervalAC = (RysCTime - RysATime)/TestPeriod
TestIntervalBC = (RysCTime - RysBTime)/TestPeriod
print("Assumed period based on first two minimums: %0.4f " % TestPer
print("Number of periods between first and third: %0.4f " % TestInte
print("Number of periods between second and third: %0.4f " % TestInt
print("Not an integer! Try again dividing by 2")
print()
TestPeriod = (RysBTime - RysATime)/2
TestIntervalAC = (RysCTime - RysATime)/TestPeriod
TestIntervalBC = (RysCTime - RysBTime)/TestPeriod
print("Period based on first two minimums / two: %0.4f " % TestPerio
print("Number of periods between first and third: %0.4f " % TestInte
print("Number of periods between second and third: %0.4f " % TestInt
print("Not bad! Gets to within %0.4f " % (100*(TestIntervalAC-11)/Te
print("Or compared to the published value, within %0.4f " % (100*(.4
PeriodUncertainty = (TestIntervalAC-11)/TestPeriod
#print(PeriodUncertainty)
```

```
Assumed period based on first two minimums: 0.9115
Number of periods between first and third: 5.5056
Number of periods between second and third: 4.5056
Not an integer! Try again dividing by 2

Period based on first two minimums / two: 0.4557
Number of periods between first and third: 11.0112
Number of periods between second and third: 9.0112
Not bad! Gets to within 2.4582  percent 'uncertainty'(?)!
Or compared to the published value, within 0.0793  percent!
```

Period-Magnitude Relationship

Absolute Magnitude, $M_v(FRE)$, was calculated as follow:

$$M_v(FRE) = +0.16 - 1.76log_{10}M - 2.20log_{10}P$$

(A mass, M, of 0.65 solar masses and metalicity, Y, of 0.24
was assumed for the purposes of this calculation.)

Distance

$Distance$, was calculated as follow:

$$Distance = 10^{(ApparentMagnitude - AbsoluteMagnitude + 5)/5}$$

In [19]:

```
#Mv_HBE = (-1.03)-(1.90*np.log10(.65))-(2.44*np.log10(TestPeriod))
Mv_FRE = (+0.16)-(1.76*np.log10(.65))-(2.20*np.log10(TestPeriod))
#print(Mv_HBE)
Mv_FRE_err_Hi = (+0.16)-(1.76*np.log10(.65))-(2.20*np.log10(TestPeri
Mv_FRE_err_Lo = (+0.16)-(1.76*np.log10(.65))-(2.20*np.log10(TestPeri
#print(Mv_FRE_err_Hi,Mv_FRE_err_Lo)
MagUncertaintyHi = Mv_FRE_err_Hi - Mv_FRE
MagUncertaintyLo = Mv_FRE - Mv_FRE_err_Lo
#print(MagUncertaintyHi,MagUncertaintyLo)
print("Absolute Magnitude: %0.4f (+/-) %0.4f" % (Mv_FRE, MagUncertai

Distance = ((10**((MeanMag-Mv_FRE+5)/5))) #Distance in parsecs
Dist_err_Hi = ((10**((MeanMag-(Mv_FRE_err_Hi)+5)/5)))
Dist_err_Lo = ((10**((MeanMag-(Mv_FRE_err_Lo)+5)/5)))
#print(Dist_err_Hi,Dist_err_Lo)
DistUncertaintyLo = Dist_err_Lo - Distance
DistUncertaintyHi = Distance - Dist_err_Hi
#print(DistUncertaintyHi,DistUncertaintyLo)
print("Distance in parsecs: %0.0f (+/-) %0.2f" % (Distance,DistUncer
print("Published distance: %0.0f " % (908.8430))
```

```
Absolute Magnitude: 1.2401 (+/-) 0.0238
Distance in parsecs: 1257 (+/-) 13.69
Published distance: 909
```

References

Maeder, André (2009). Physics, formation and evolution of rotating stars. Astronomy and astrophysics library. Springer. p. 373. ISBN 978-3-540-76948-4.

Collins, K. (2017). AstroImageJ: Image Processing and Photometric Extraction for Ultra-Precise Astronomical Light Curves (Expanded Edition) arXiv:1701.04817v1

Caputo, Filippina (1997). The Period-Magnitude Diagram for RR Lyrae Stars - I. The controversy about the distance scale 1997MNRAS.284..994C