404 final assignment-Copy1

April 27, 2022

0.1 ASTR 404 Assignment – Kennedy Robinson – April 27th 2022

[65]:
```
import numpy as np
import matplotlib.pyplot as plt
%pylab nbagg
%matplotlib inline
```

```
Populating the interactive namespace from numpy and matplotlib
```

0.2 Importing the data

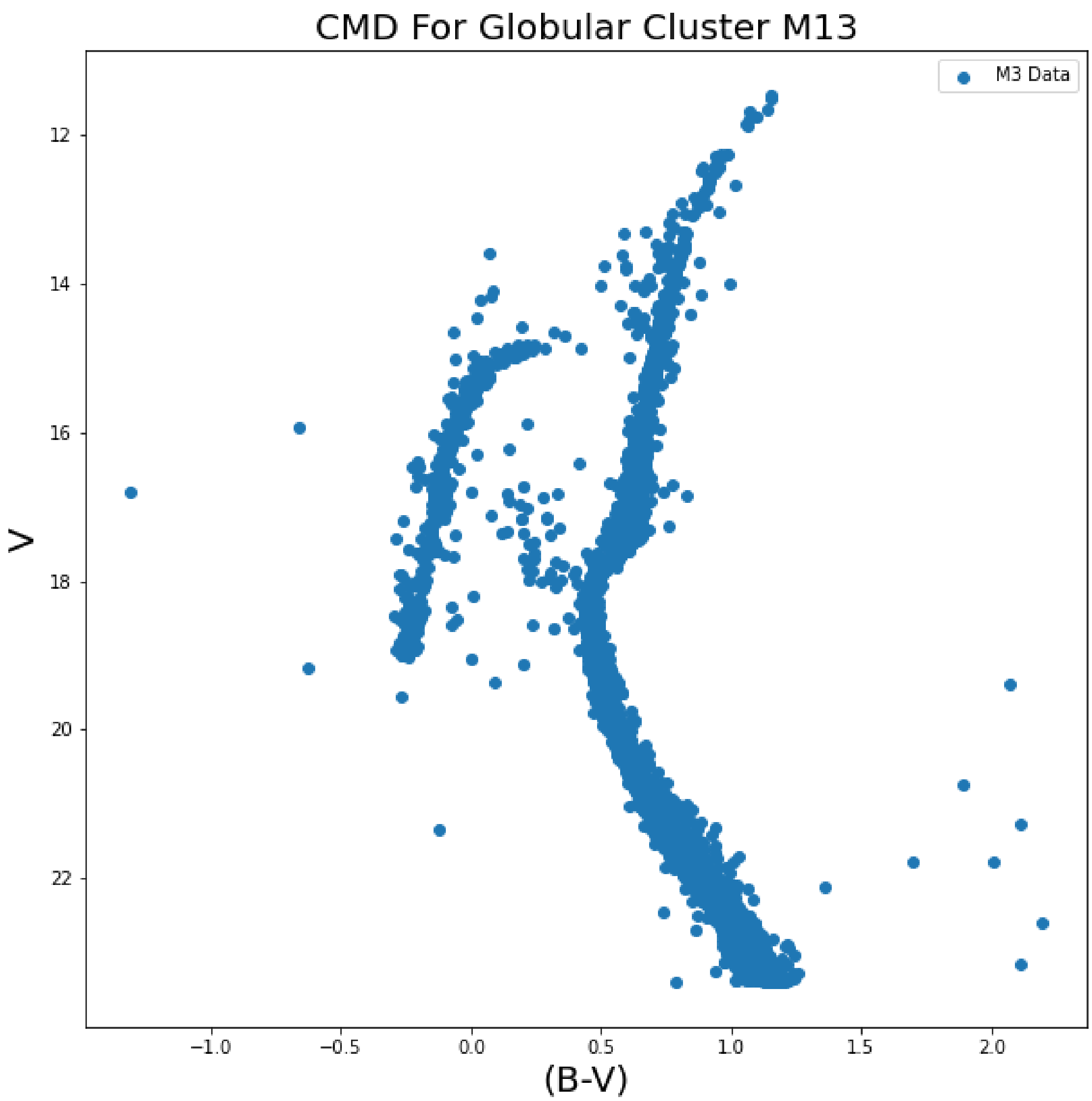
[66]:
```
M13_data = np.genfromtxt('Photo/m13data2.txt',dtype=float)
mag = np.array([row[0] for row in M13_data])
color = [row[1]for row in M13_data]
```

[67]:
```
M13_data = open
```

0.3 Plotting the CMD for the M13 Cluster

[68]:
```
plt.figure(figsize=(10,10))
plt.scatter(color,mag)
plt.gca().invert_yaxis()
plt.title('CMD For Globular Cluster M13',fontsize=20)
plt.xlabel('(B-V)',fontsize=20)
plt.ylabel('V',fontsize=20)
plt.legend(["M3 Data"])
```

[68]:
```
<matplotlib.legend.Legend at 0x7fe512b6ebb0>
```



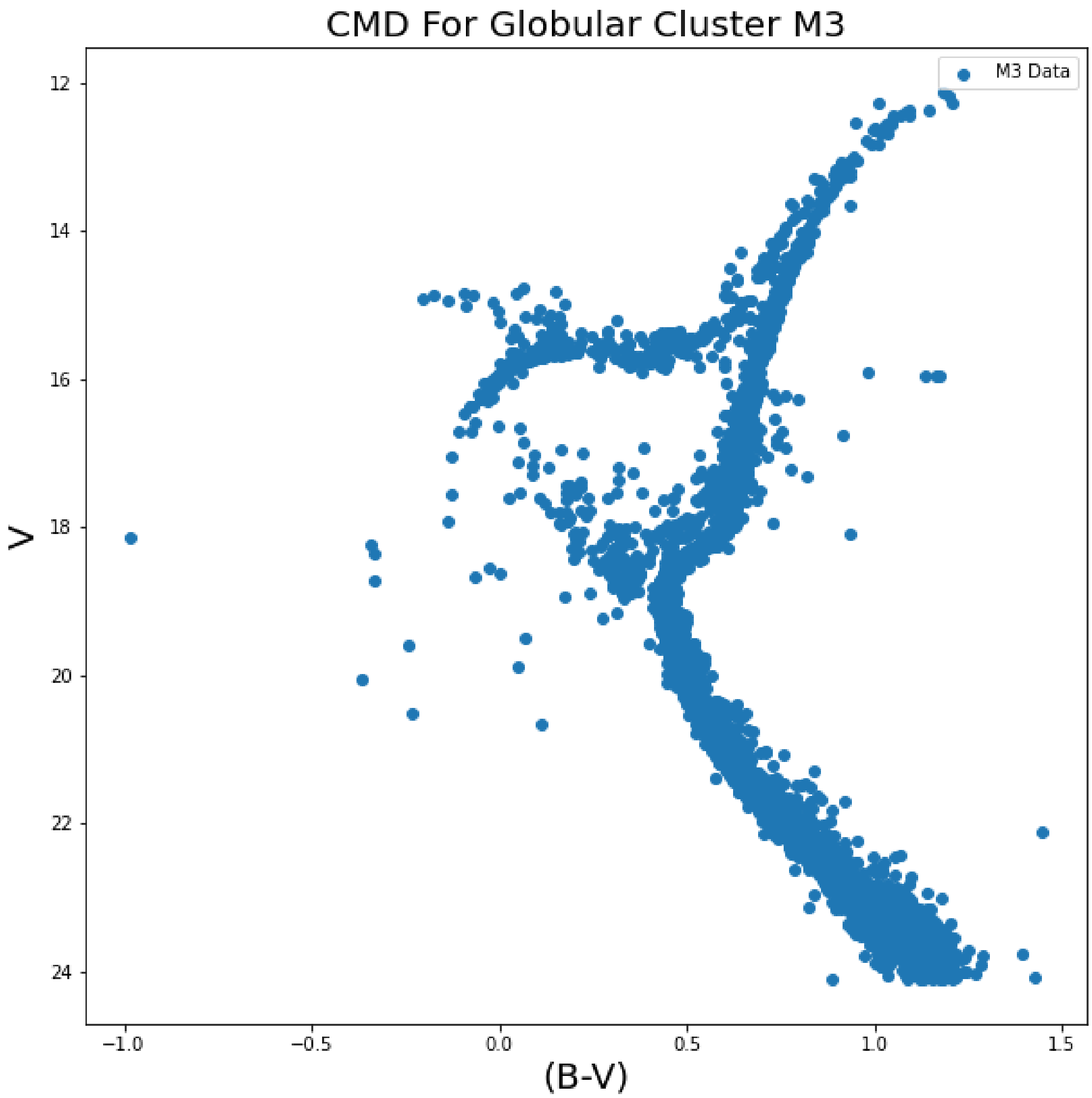
[69]:
```
M3_data = np.genfromtxt('Photo/M3data.txt',dtype=float)
mag3 = np.array([row[0] for row in M3_data])
color3 = [row[1]for row in M3_data]
```

0.4 Plotting the CMD for the M3 Cluster

[70]:
```
plt.figure(figsize=(10,10))
plt.scatter(color3,mag3)
plt.gca().invert_yaxis()
plt.title('CMD For Globular Cluster M3',fontsize=20)
plt.xlabel('(B-V)',fontsize=20)
plt.ylabel('V',fontsize=20)
```

```
plt.legend(["M3 Data"])
```

[70]: <matplotlib.legend.Legend at 0x7fe512e1eb50>



0.5 Note the difference between morphologies of their HBs. This is a manifestation of the second parameter problem, when two globular clusters with a same [Fe/H] have different HBs. Its possible solutions are differences in the age or in the initial helium mass fraction.

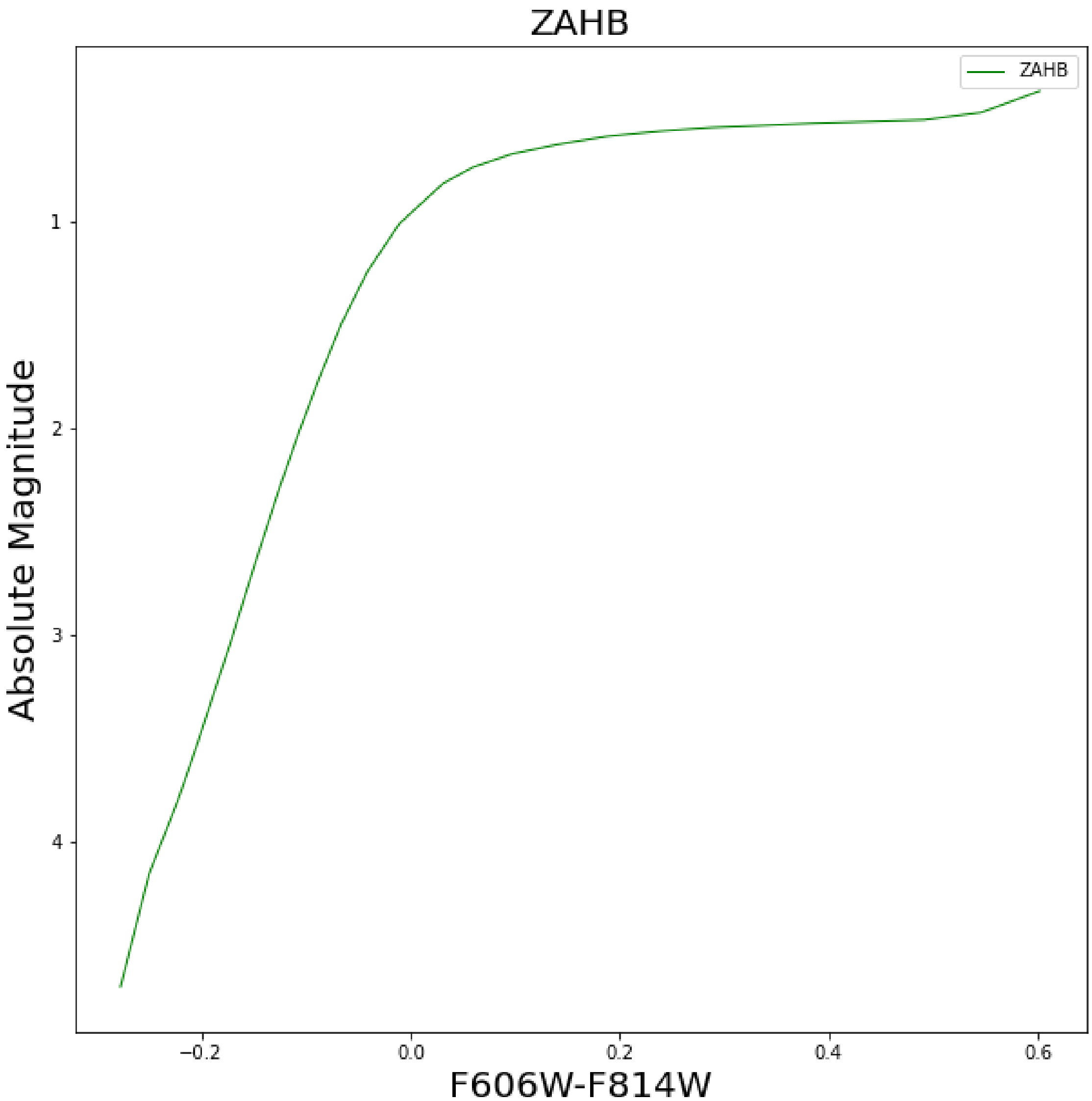
The clusters are almost identical in most aspects such as chemical composition, however, there are noticable differences in the clusters horizantal-branch and blue straggler populations. The HB in M13 has a long blue tail extending below the main sequence turnoff point, whereas the HB of M3 does not. M13 also has noticable gaps in the HB. This indicates that M13 and M3 are a case of the second-parameter problem in the HB morphology. It also appears that M3 has a larger frequency of blue stragglers compare to M13.

[116]:
```
ZAHB = np.genfromtxt('Photo/ZAHB.txt',dtype=float)
abs_mag= np.array([row[7] for row in ZAHB])
abs_color = [row[8]for row in ZAHB]
```

0.6 Plotting the ZAHB

[117]:
```
plt.figure(figsize=(10,10))
plt.gca().invert_yaxis()
plt.title('ZAHB',fontsize=20)
plt.xlabel('F606W-F814W',fontsize=20)
plt.ylabel('Absolute Magnitude',fontsize=20)
plt.plot(abs_color,abs_mag,'g-',linewidth=1)
plt.legend(["ZAHB"])
```

[117]:
```
<matplotlib.legend.Legend at 0x7fe51252ff40>
```

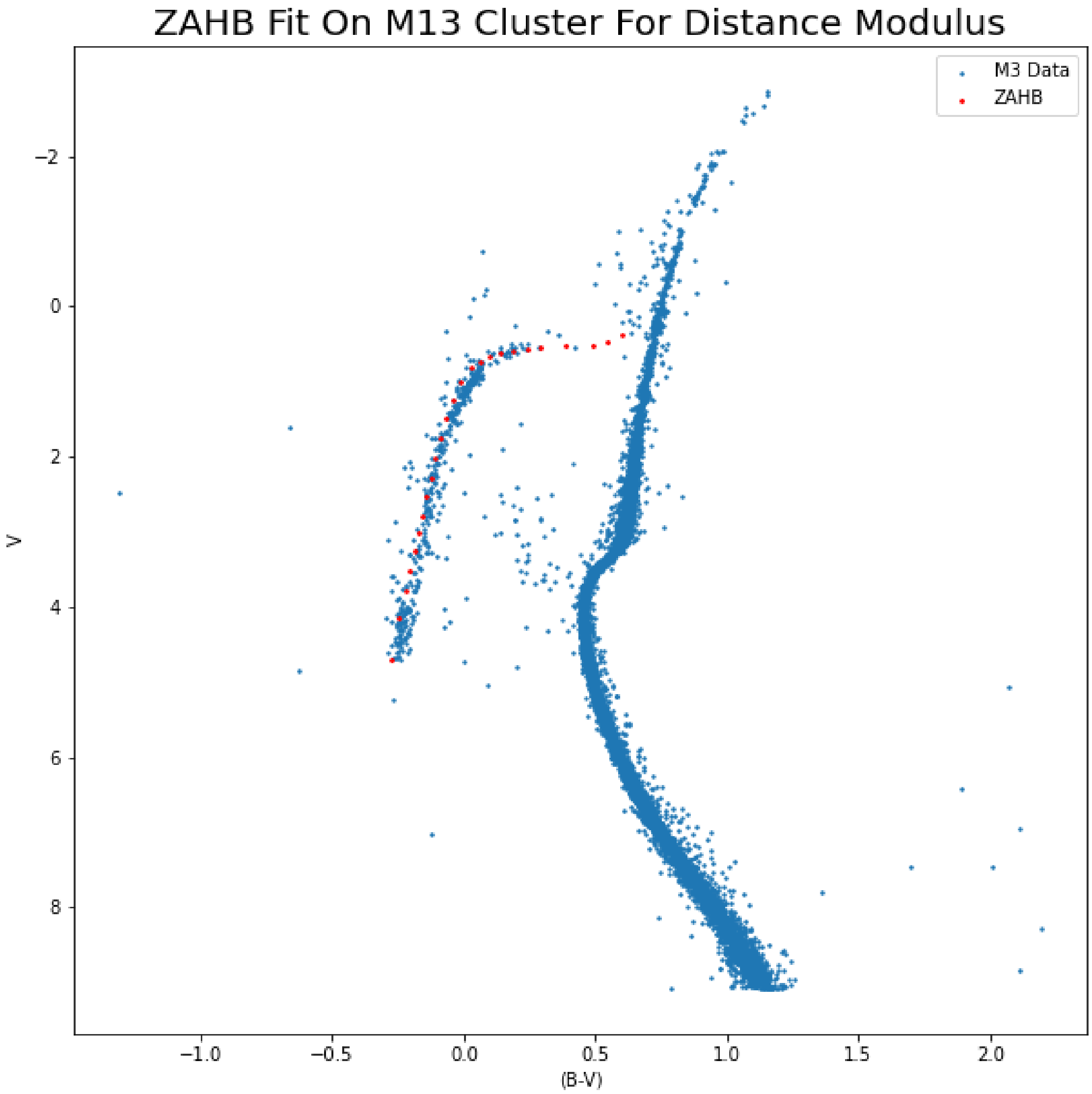


0.7 Finding the apparent distance moduli for the M13 Cluster by vertically shifting the M13 data to align with the ZAHB

[118]:
```
App_dist13 = []

for i in range(len(mag)):
    App_dist13.append(mag[i] - 14.32)

plt.figure(figsize=(10,10))
plt.scatter(color,App_dist13, s = 2)
plt.scatter(abs_color,abs_mag, s = 3 , color = 'RED')
plt.gca().invert_yaxis()
```

```
plt.title('ZAHB Fit On M13 Cluster For Distance Modulus', fontsize=20)
plt.xlabel('(B-V)')
plt.ylabel('V')
plt.legend(["M3 Data","ZAHB"])
```

[118]: <matplotlib.legend.Legend at 0x7fe5125003d0>

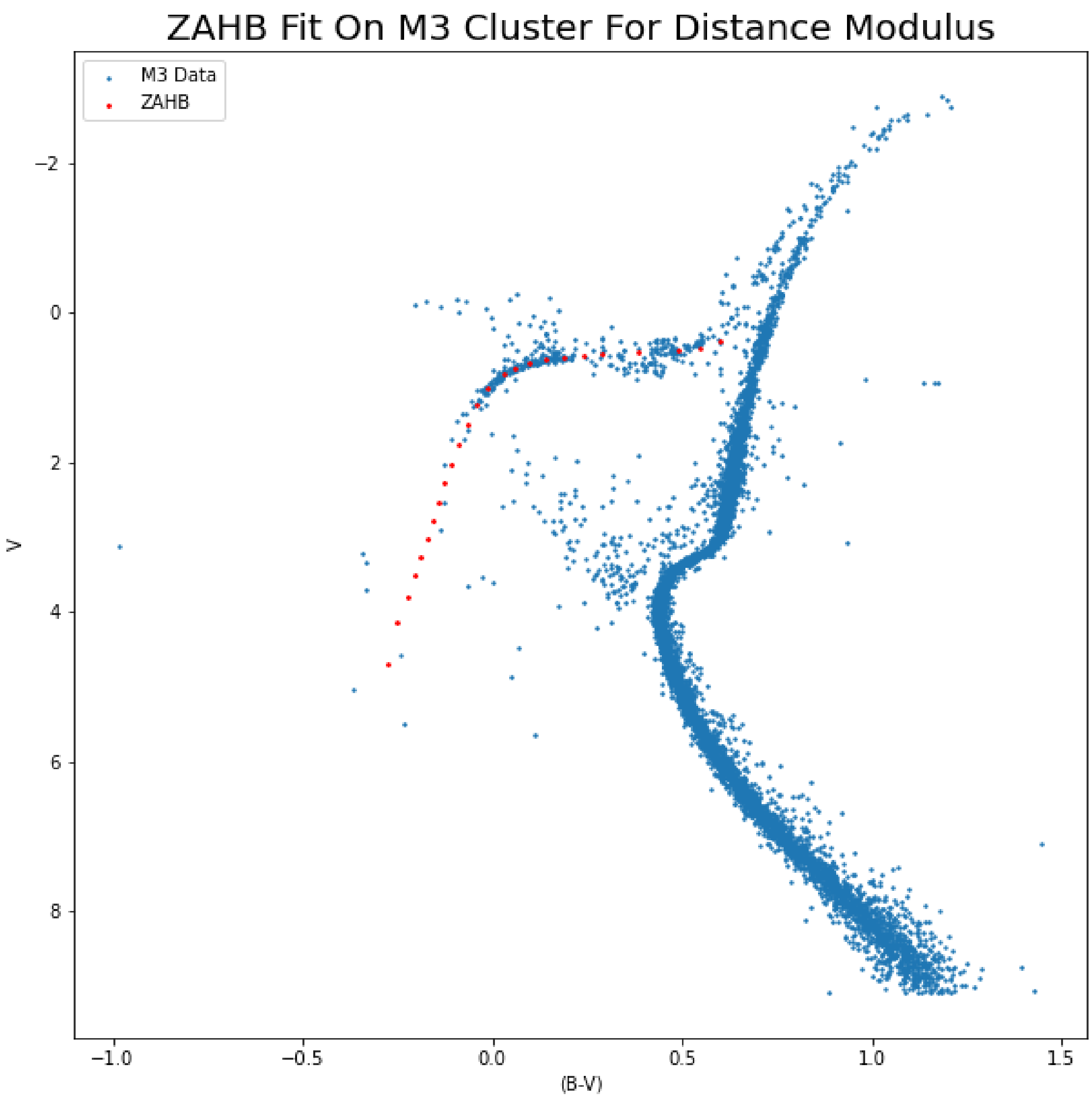


0.8 The best fitting value of the apparent distance for M13 appears to be Dv = 14.32

0.9 Finding the apparent distance moduli for the M3 Cluster by vertically shifting the M3 data to align with the ZAHB

[119]:
```
App_dist3 = []

for i in range(len(mag3)):
    App_dist3.append(mag3[i] - 15.015)

plt.figure(figsize=(10,10))
plt.scatter(color3,App_dist3, s = 2)
plt.scatter(abs_color,abs_mag, s = 3 , color = 'RED')
plt.gca().invert_yaxis()
plt.title('ZAHB Fit On M3 Cluster For Distance Modulus', fontsize=20)
plt.xlabel('(B-V)')
plt.ylabel('V')
plt.legend(["M3 Data","ZAHB"])
```

[119]:
```
<matplotlib.legend.Legend at 0x7fe5124a8dc0>
```



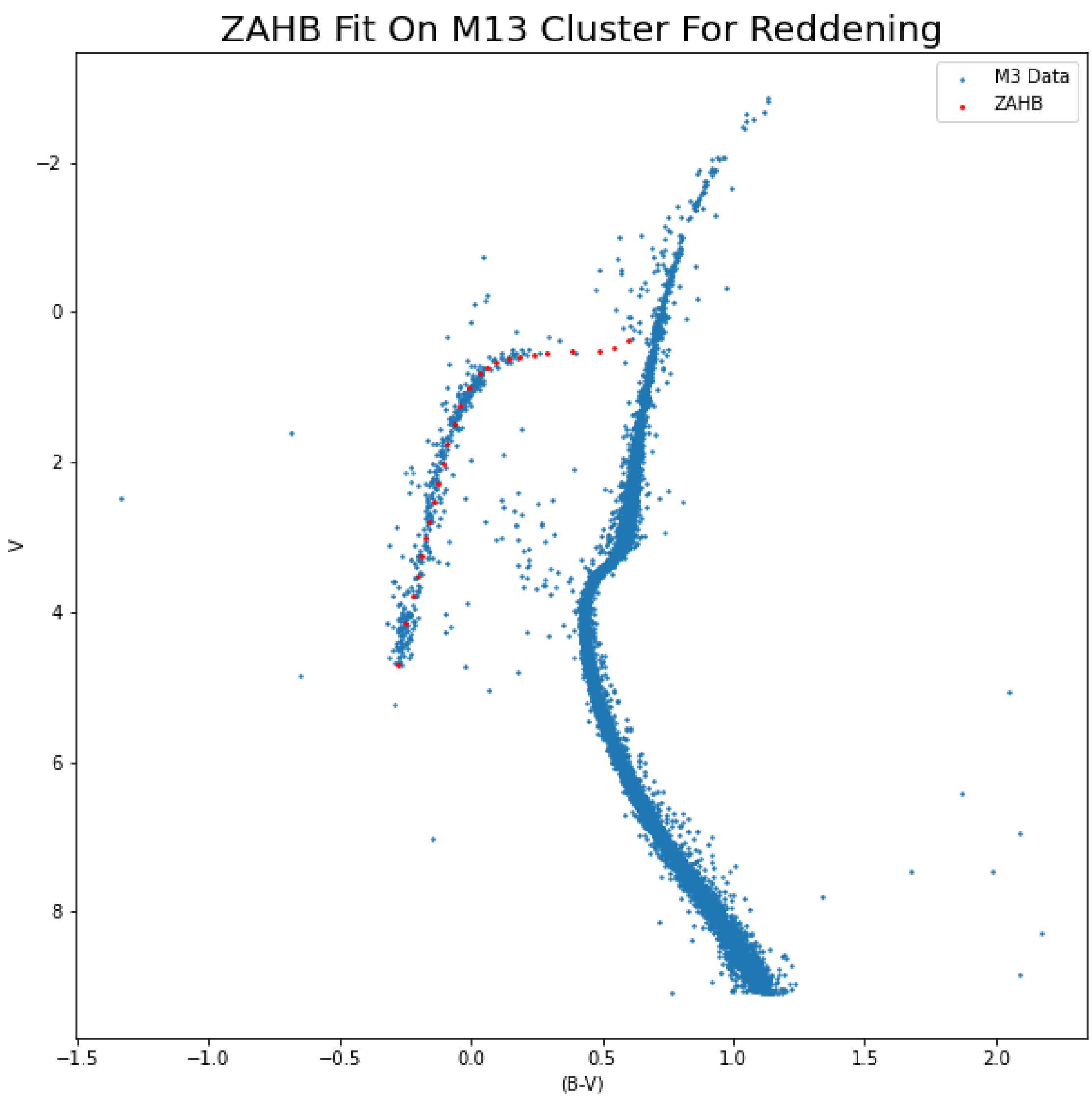
0.10 The best fitting value of the apparent distance for M3 appears to be Dv = 15.015

0.11 Fnding the reddening for the M13 cluster by horizantally shifting the M13 data for align with the ZAHB

[120]:
```
App_dist13 = []
redM13 = []

for i in range(len(mag)):
    App_dist13.append(mag[i] - 14.32)

for j in range(len(color)):
```

```
    redM13.append(color[j] - 0.022)

plt.figure(figsize=(10,10))
plt.scatter(redM13,App_dist13, s = 2)
plt.scatter(abs_color,abs_mag, s = 3 , color = 'RED')
plt.gca().invert_yaxis()
plt.title('ZAHB Fit On M13 Cluster For Reddening',fontsize=20)
plt.xlabel('(B-V)')
plt.ylabel('V')
plt.legend(["M3 Data","ZAHB"])
```

[120]: <matplotlib.legend.Legend at 0x7fe5123daa00>

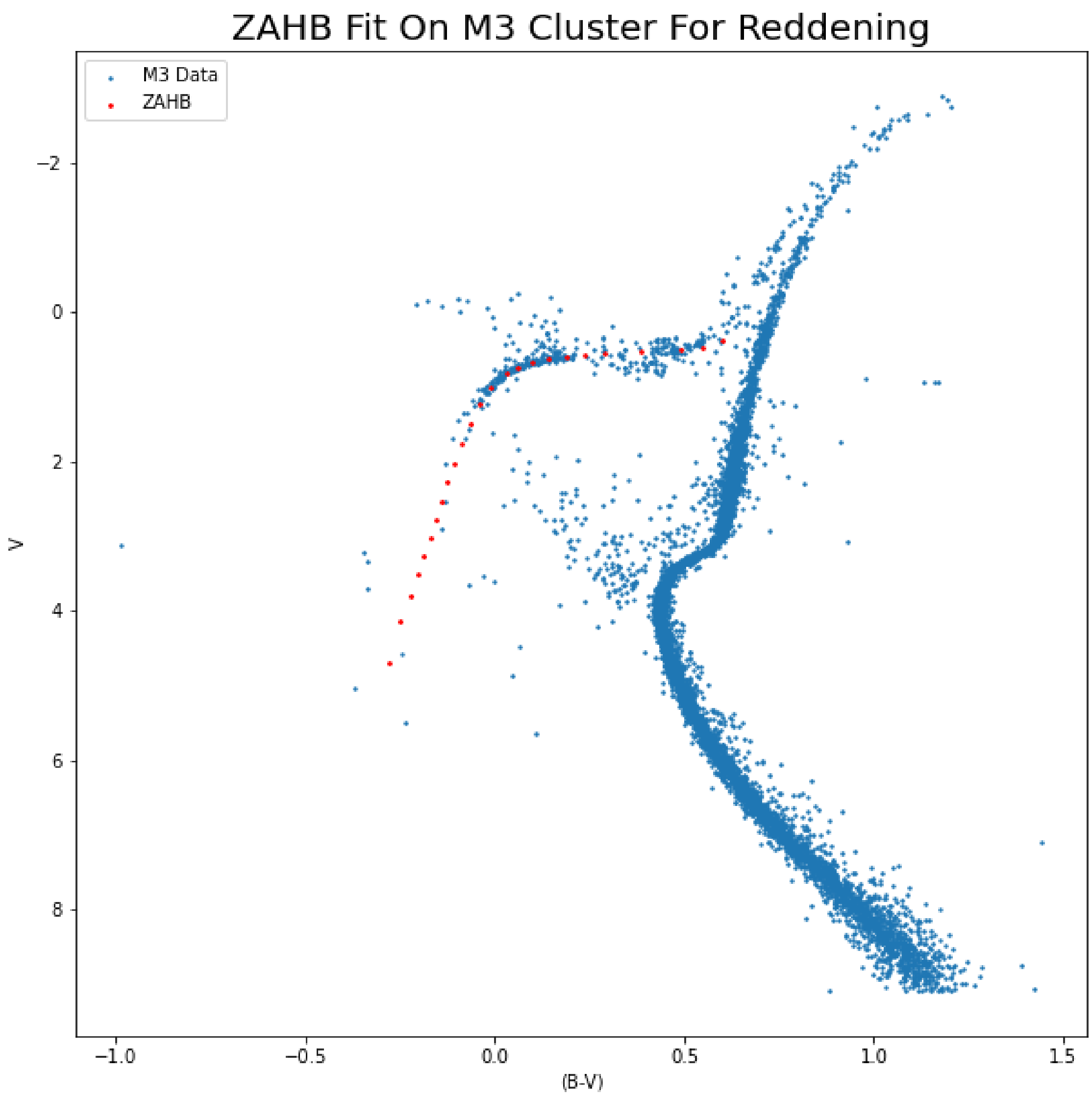


0.12 The best fitting value of E(B-V) for M13 seems to be 0.022

0.13 Finding the reddening of the M3 cluster by horizantally shifting the M3 data to fit the ZAHB

[121]:
```
App_dist3 = []
redM3 = []



for i in range(len(mag3)):
    App_dist3.append(mag3[i] - 15.015)

for j in range(len(color3)):
    redM3.append(color3[j] - 0.004)


plt.figure(figsize=(10,10))
#plt.scatter(color3,mag3, s = 2)
#plt.scatter(abs_color,App_dist, s = 3 , color = 'RED')
plt.scatter(redM3,App_dist3, s = 2)
plt.scatter(abs_color,abs_mag, s = 3 , color = 'RED')
plt.gca().invert_yaxis()

plt.title('ZAHB Fit On M3 Cluster For Reddening',fontsize=20)
plt.xlabel('(B-V)')
plt.ylabel('V')
plt.legend(["M3 Data","ZAHB"])
```

[121]:
```
<matplotlib.legend.Legend at 0x7fe512346c70>
```



0.14 The best fitting value of E(B-V) for M3 seems to be 0.0055

0.15 So the value of the reddening for the Clusters is: Av = 2.876*E(B-V)

[122]:
```
Rv = 2.876
B_V_m13 = 0.022
B_V_m3 = 0.004
Av_m13 = Rv*B_V_m13
Av_m3 = Rv*B_V_m3
print("The reddening for the M13 cluster is Av =", Av_m13)
print("The reddening for the M3 cluster is Av =", Av_m3)
```

```
The reddening for the M13 cluster is Av = 0.063272
```

```
The reddening for the M3 cluster is Av = 0.011504
```

0.16 True distance moduli calculation: Dv0 = Dv - Av

[123]:
```python
App_Dv_M13 = 14.32
App_Dv_M3 = 15.015
```

[124]:
```python
Dvo_M13 = App_Dv_M13 - Av_m13
print("The true distance moduli for the M13 cluster is:", Dvo_M13)
Dvo_M3 = App_Dv_M3 - Av_m3
print("The true distance moduli for the M3 cluster is:", Dvo_M3)
```

```
The true distance moduli for the M13 cluster is: 14.256728
The true distance moduli for the M3 cluster is: 15.003496
```

0.17 Comparing the values I found vs those on catalogue http://physwww.physics.mcmaster.ca/%7Eharris/mwgc.dat

0.17.1 The Catalogues Apparent visual distance modulus values are:

For M13: (m-M)v = 14.33 and For M3: (M-M)v = 15.07 ### Compared to my measured values of the apparent visual distance modulus: For M13: (m-M)v = 14.32 and For M3: (M-M)v = 15.015

0.17.2 The catalogues values of E(B-V) are:

For M13: E(B-V) = 0.02 and For M3: E(B-V) = 0.01

0.17.3 Compared to my measured values of E(B-V):

For M13: E(B-V) = 0.022 and For M3: E(B-V) = 0.004

[125]:
```python
##Calculating the precent error for apparent distance:

PErr_DM13 = (np.abs(14.33-14.32)/14.33)*100
print("The % error in M13 apparent distance is:",PErr_DM13)

PErr_DM3 = (np.abs(15.07-15.015)/15.07)*100
print("The % error in M3 apparent distance is:",PErr_DM3)
```

```
The % error in M13 apparent distance is: 0.06978367062107318
The % error in M3 apparent distance is: 0.36496350364963315
```

[126]:
```python
## Calculating percent error for reddening (B-V):

PRed_ErrM13 =  (np.abs(0.02-0.022)/0.02)*100
print("The % error in M13 (B-V) is:", PRed_ErrM13)

PRed_ErrM3 = (np.abs(0.01-0.004)/0.01)*100
print("The % error in M3 (B-V) is:", PRed_ErrM3)
```

```
The % error in M13 (B-V) is: 9.999999999999991
The % error in M3 (B-V) is: 60.0
```

The percent error in the reddening is most likely high as the two clusters have relatively low reddedning and therefore, the measurement must be very accurate to minimize error. In order to ahcieve a more accruate value, the plot size would have to be increased in order to acheive a more cacurate fit to the ZAHB.

d = 10[1] ; where (m-M) is equal to the apparent distance found from the plots.

[128]:
```
#x = (App_Dv_M3)/5
#y = x + 1
#Dist_M3 = 10**(y)
#DM3 = Dist_M3/1000
#print("The calcualted distance to M3 is",Dist_M3, "pc")
#xx = (App_Dv_M13)/5
#yy = xx + 1
#Dist_M13 = 10**(yy)
#DM13 = Dist_M13/1000
#print("The calcualted distance to M13 is",Dist_M13, "pc")
```

0.18 Distance calculations using the distance modulus relation and taking into accound reddening:

d = 10[2]; where (m-M) is equal to the apparent distance found from the plots.

[129]:
```
L = ((App_Dv_M3) + 5)
ll = L - Av_m3
LLL = 0.2*ll
LLL
Dis_M3 = 10**(LLL)
Dis_M3
print("The calcualted distance to M13 taking into account the reddening␣
↪is",Dis_M3, "pc")
```

```
The calcualted distance to M13 taking into account the reddening is
10016.112641904781 pc
```

[130]:
```
S = ((App_Dv_M13) + 5)
SS = S - Av_m13
SSS = 0.2*SS
dis_M13 = 10**(SSS)
dis_M13
print("The calcualted distance to M13 taking into account the reddening␣
↪is",dis_M13, "pc")
```

[1] (m-M)/5 + 1
[2] 0.2((m-M) + 5 - Av

The calcualted distance to M13 taking into account the reddening is
7101.426558136958 pc

Looking up the true measured distances to the clusters to compare I found that the real distance to M3 is 10424.447 pc and the real distance to M13 is 6800.4189 pc. Therefore the values I measured for the distance are not far off.

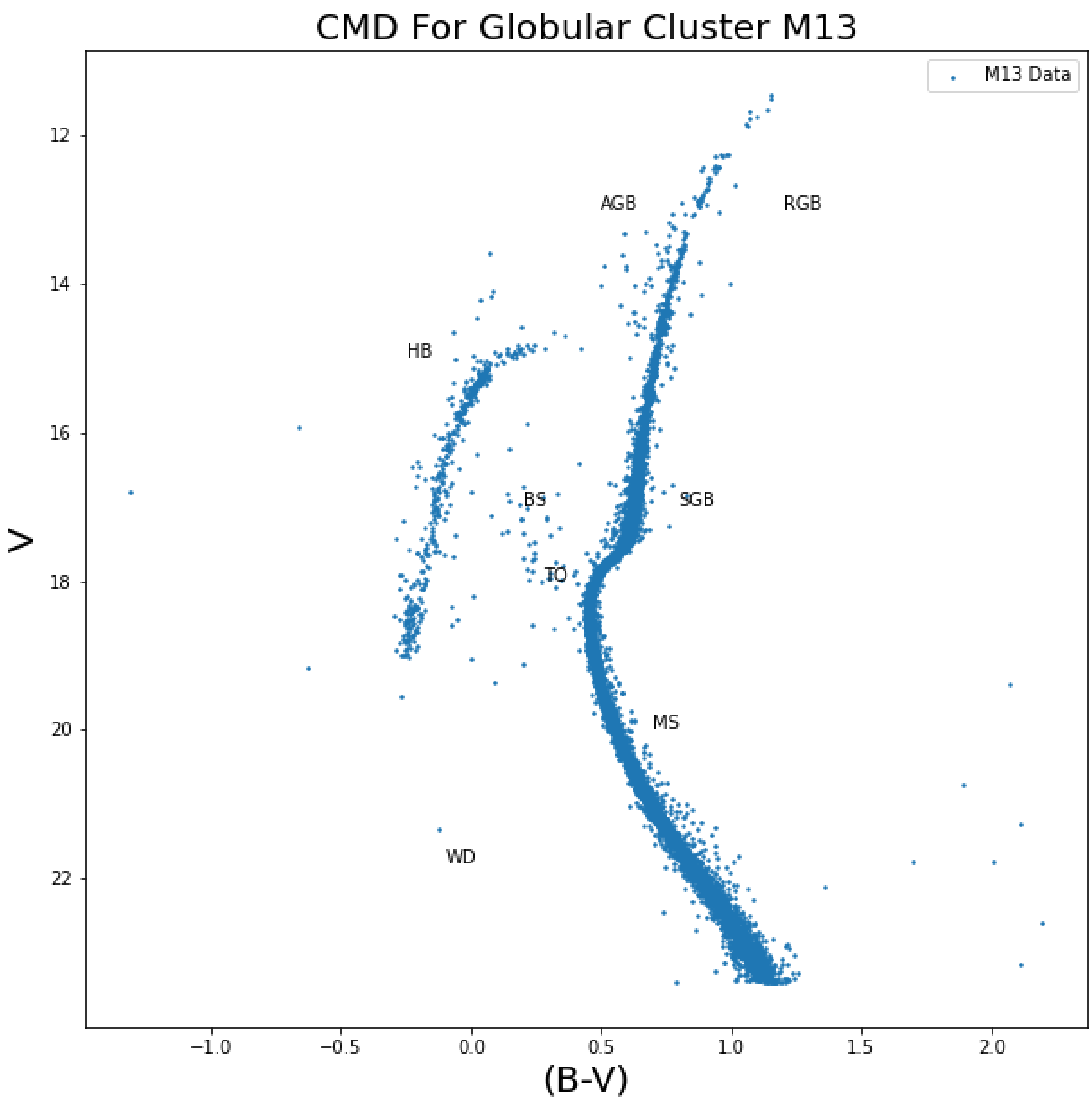
[132]:
```
## Percent error in distance calculations including reddening:

PE_DM13 = (np.abs(6800.4189-7101.426558136958)/6800.4189)*100
print('The % error in distance calculation to M13 is:',PE_DM13 )

PE_DM3 = (np.abs(10424.447-10016.112641904781)/10424.447)*100
print('The % error in distance calculation to M3 is:',PE_DM3 )
```

```
The % error in distance calculation to M13 is: 4.4263105341489855
The % error in distance calculation to M3 is: 3.9170841205794296
```

0.19 Marking the major evolutionary phases along the plotted CMDs:

[133]:
```
plt.figure(figsize=(10,10))
plt.scatter(color,mag, s = 2)



plt.title('CMD For Globular Cluster M13',fontsize=20)
plt.xlabel('(B-V)',fontsize=20)
plt.ylabel('V',fontsize=20)



plt.text(0.7,20, f'MS') #main sequence
plt.text(0.5,13,"AGB") #Asymptotic giant branch
plt.text(1.2,13, f'RGB')  #red giant branch
plt.text(0.28,18, f'TO')  #turn off
plt.text(-0.25,15, f'HB')   #Horizontal Branch
plt.text(0.2,17,"BS")   #blue stragglers
plt.text(0.8,17,"SGB")   #sub giant branch
plt.text(-0.1,21.8,"WD") #white dwarf
plt.gca().invert_yaxis()
plt.legend(["M13 Data"])
```

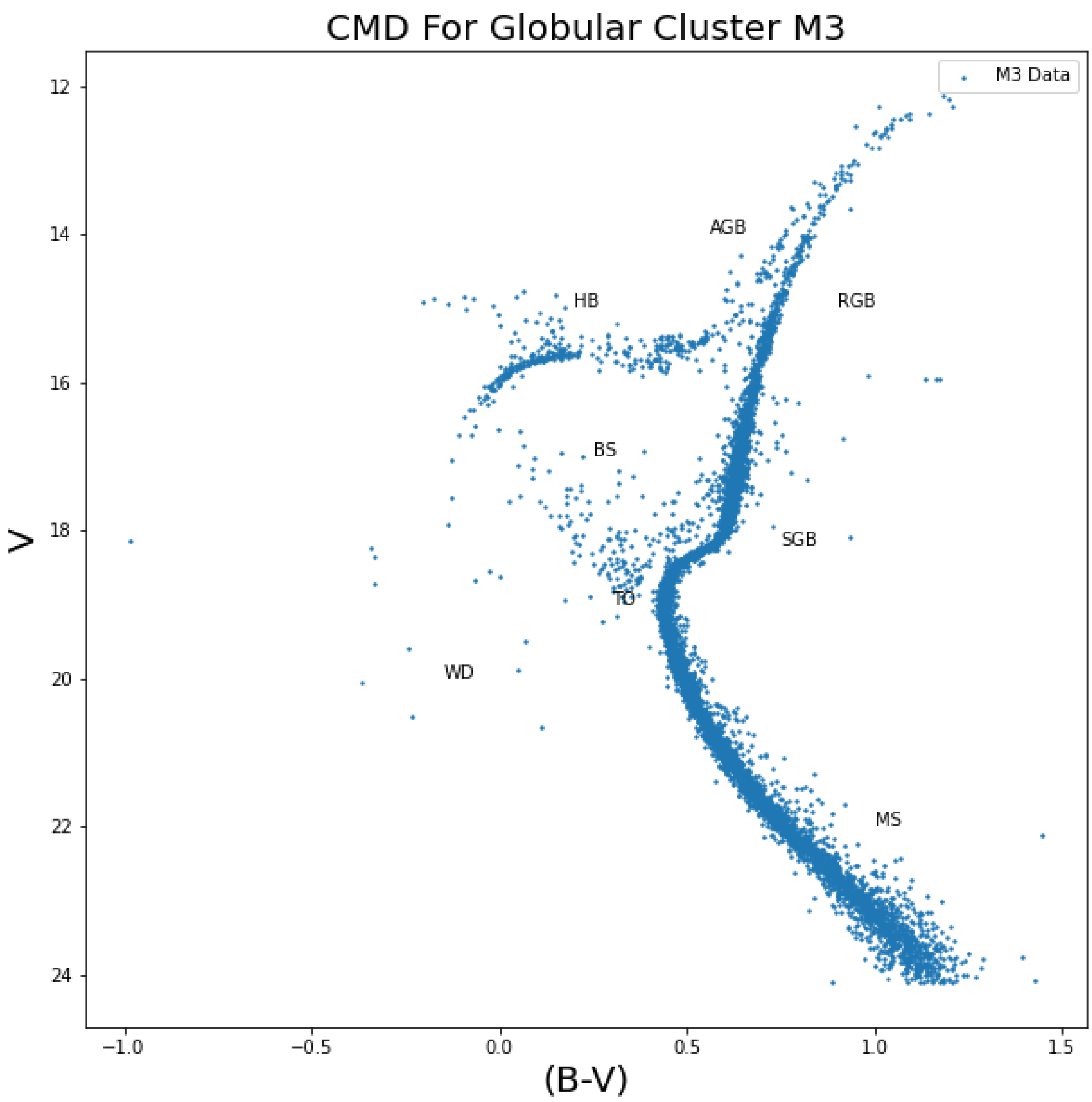
[133]: <matplotlib.legend.Legend at 0x7fe512389e50>



[134]:
```
plt.figure(figsize=(10,10))
plt.scatter(color3,mag3, s = 2)
plt.gca().invert_yaxis()
plt.title('CMD For Globular Cluster M3',fontsize=20)
plt.xlabel('(B-V)',fontsize=20)
plt.ylabel('V',fontsize=20)


plt.text(1,22, f'MS')#main sequence
plt.text(0.56,14, f'AGB')#Asymptotic giant branch
plt.text(0.9,15, f'RGB')#red giant branch
plt.text(0.3,19, f'TO') #turn off
plt.text(0.2,15, f'HB') #Horizontal Branch
```

```
plt.text(0.25,17,"BS") #blue stragglers
plt.text(0.75,18.2,"SGB") #sub giant branch
plt.text(-0.15,20,"WD") #white dwarf

#plt.xlabel("(F606W - F814W) Colour")
#plt.ylabel("F606W Apparent Magnitude")

plt.legend(["M3 Data","ZAHB"])
```

[134]: <matplotlib.legend.Legend at 0x7fe512272e20>



[ ]: