pulsar2

November 4, 2022

1 Pulsar Emission Data Analysis

2 All Imports that may or may not be needed and used for the notebook

[ ]:
```
#currently including any and all Imports that maybe needed for the project.
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline
from sklearn.model_selection import train_test_split
from sklearn import linear_model
from sklearn.metrics import r2_score, mean_squared_error
from sklearn.linear_model import LogisticRegression, LinearRegression
from sklearn.metrics import confusion_matrix, accuracy_score
from sklearn.feature_selection import RFE
import datetime as dt
from sklearn.cluster import KMeans
from sklearn.metrics import pairwise_distances
from scipy.cluster.hierarchy import linkage, dendrogram, cut_tree
from scipy.spatial.distance import pdist
from sklearn.feature_extraction.text import TfidfVectorizer
import matplotlib.dates as mdates
from scipy.stats import pearsonr
from scipy import stats
import statistics
import math
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
from statsmodels.tsa.stattools import acf, pacf
from statsmodels.tsa.tsatools import lagmat
from numpy import array
from sklearn.model_selection import train_test_split
from keras.models import Sequential
from keras.layers import LSTM
from keras.layers import Dense
from keras.layers import Bidirectional
```

3 Section for extracting from a tar file.

Currently implemented for original TAR File structure.

[ ]:
```
#This is also found in the main file under tarunzip.py
import tarfile
import os
import sys

#tar = tarfile.open("pulseTarFile.tar")
#tar.extractall('./Data')
#tar.close()
```

3.1 Beginning of Exploration

3.1.1 Examining the data

In this section we are determining the total integrity of the data to determine if further comprehensive data cleaning and uniforming processes are needed.

[ ]:
```
colnames = ['Pulse Number', 'Brightness', 'Uncertainty']
pulsar = pd.read_csv("Data/J0953+0755.pulses", sep = ' ', header = None, names␣
 ↪= colnames)
```

[ ]:
```
pulsar.shape
```

[ ]:
```
(14329, 3)
```

[ ]:
```
pulsar.head(25)
```

[ ]:

	Pulse Number	Brightness	Uncertainty
0	1	0.334330	0.015570
1	2	-0.098659	0.014051
2	3	0.123514	0.011901
3	4	0.443923	0.014365
4	5	1.590446	0.057785
5	6	1.233848	0.018692
6	7	0.857876	0.022208
7	8	0.254255	0.018185
8	9	0.292077	0.021672
9	10	0.439929	0.046293
10	11	0.824310	0.036243
11	12	1.443460	0.088372
12	13	0.127981	0.018070
13	14	0.327896	0.012362
14	15	2.473663	0.099205
15	16	0.683800	0.049683
16	17	0.744937	0.033909
17	18	0.628764	0.032342
18	19	5.077294	0.093078

```
19            20    0.554981     0.025086
20            21    1.006799     0.029068
21            22    4.359872     0.091381
22            23    1.576034     0.030928
23            24    1.218368     0.067754
24            25    1.377933     0.036103
```

[ ]:
```
pulsar.describe()
```

[ ]:
```
        Pulse Number    Brightness   Uncertainty
count  14329.000000  14329.000000  14329.000000
mean    7165.000000      0.994458      0.034561
std     4136.570339      1.211127      0.029641
min        1.000000     -0.219110      0.010120
25%     3583.000000      0.184157      0.014351
50%     7165.000000      0.481894      0.021999
75%    10747.000000      1.337406      0.043380
max    14329.000000      8.552022      0.242041
```

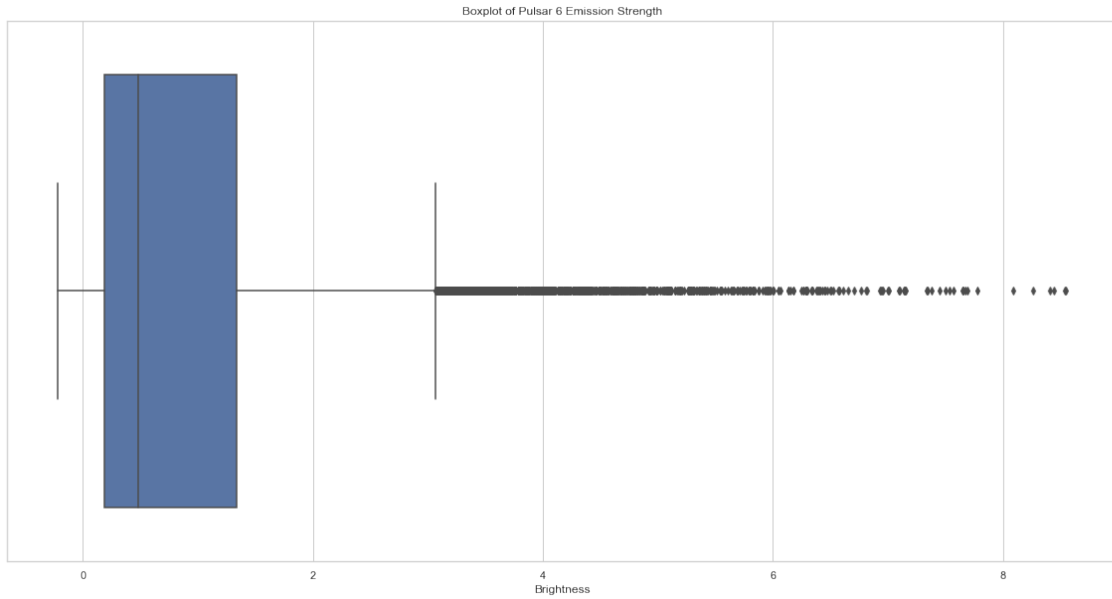
[ ]:
```
nullBoolBrightness = pd.isnull(pulsar["Brightness"])

pulsar[nullBoolBrightness]
```

[ ]:
```
Empty DataFrame
Columns: [Pulse Number, Brightness, Uncertainty]
Index: []
```

[ ]:
```
pulsar["Brightness"].describe()
```

[ ]:
```
count    14329.000000
mean         0.994458
std          1.211127
min         -0.219110
25%          0.184157
50%          0.481894
75%          1.337406
max          8.552022
Name: Brightness, dtype: float64
```

[ ]:
```
plt.figure(figsize=(20,10))
sns.set_theme(style="whitegrid")
ax = sns.boxplot(x=pulsar["Brightness"]).set_title("Boxplot of Pulsar 6␣
↪Emission Strength")
```




```
[ ]: medianpulse6 = pulsar["Brightness"].median()
     print("Median of Pulsar6: ", medianpulse6)
     pulsar['Binary'] = np.where(pulsar['Brightness'] > medianpulse6, 1, 0)
```

```
Median of Pulsar6:  0.4818942
```

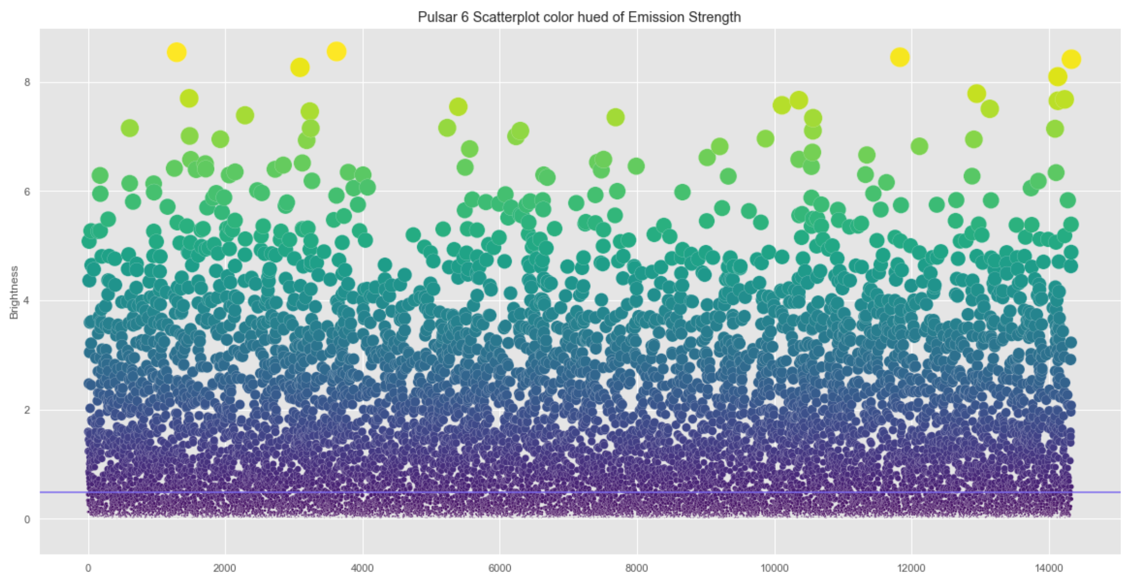
```
[ ]: pulsar
```

```
[ ]:        Pulse Number  Brightness  Uncertainty  Binary
     0                 1    0.334330     0.015570       0
     1                 2   -0.098659     0.014051       0
     2                 3    0.123514     0.011901       0
     3                 4    0.443923     0.014365       0
     4                 5    1.590446     0.057785       1
     …              …          …          …       …
     14324         14325    4.876881     0.097181       1
     14325         14326    2.074136     0.080444       1
     14326         14327    0.585504     0.026204       1
     14327         14328    0.360930     0.035051       0
     14328         14329    8.409811     0.120164       1

     [14329 rows x 4 columns]
```

```
[ ]: plt.figure(figsize=(20,10))
     sns.set_style("darkgrid", {"axes.facecolor": ".75"})
     strength = pulsar.Brightness.values
     plt.style.use('ggplot')
```

```
ax = sns.scatterplot(data=pulsar["Brightness"], s= strength*50, c=strength,␣
↪cmap="viridis", marker="o").set_title('Pulsar 6 Scatterplot color hued of␣
↪Emission Strength')
ax= plt.axhline( y=0.4818942, ls='-',c='mediumslateblue')
```

```
C:\Users\tajki\anaconda3\lib\site-packages\matplotlib\collections.py:1003:
RuntimeWarning: invalid value encountered in sqrt
  scale = np.sqrt(self._sizes) * dpi / 72.0 * self._factor
```



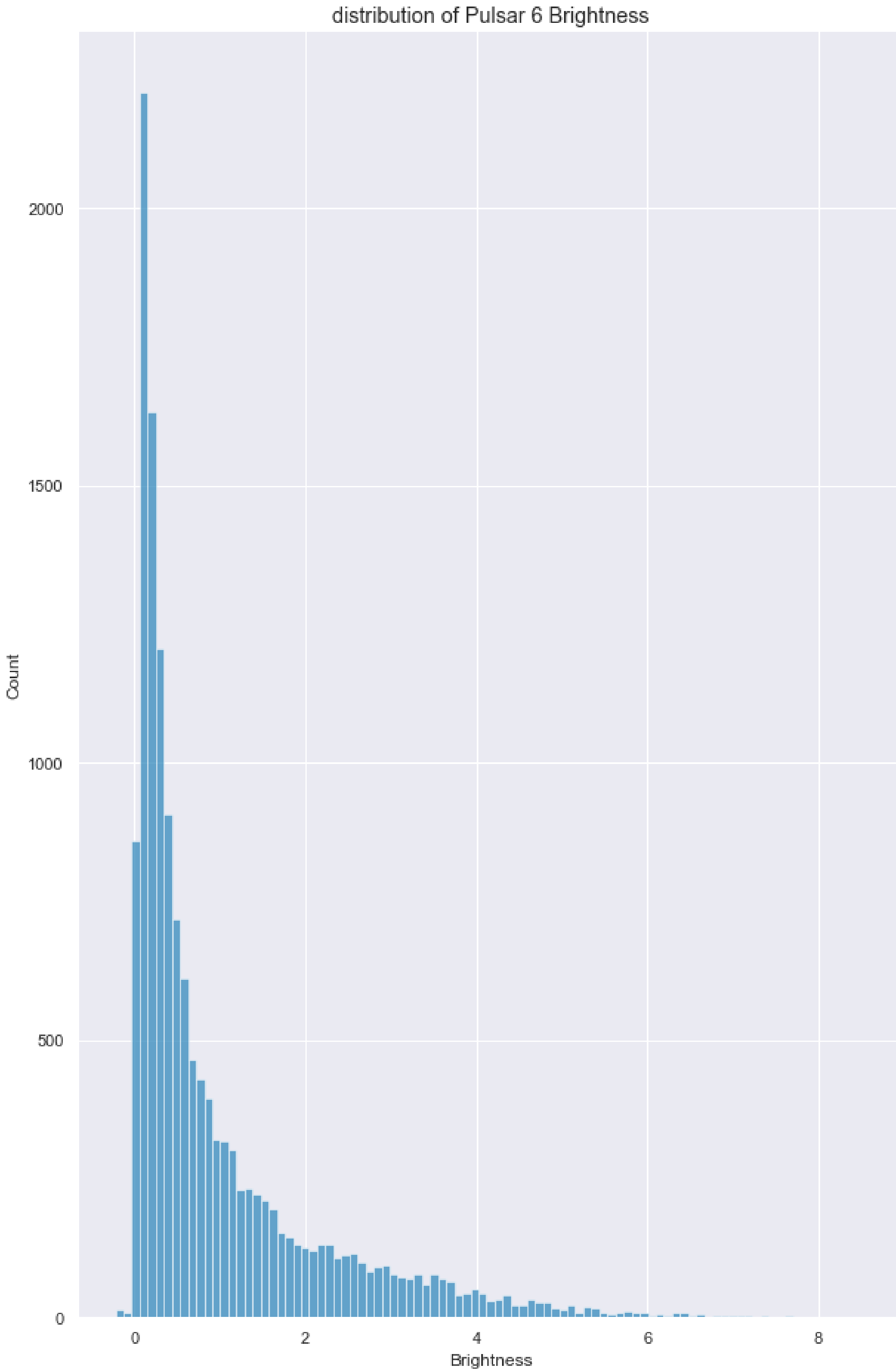
[ ]:
```
print(len(pulsar[(pulsar.Brightness > 0.4818942)]))
print(len(pulsar[(pulsar.Brightness < 0.4818942)]))
```

```
7164
7164
```

[ ]:
```
#plt.figure(figsize=(20,10))
#sns.set_style("darkgrid", {"axes.facecolor": ".75"})
#strength = pulsar.Brightness.values
#ax = plt.axhline( y=0.4818942, ls='-',c='mediumslateblue')
#ax = sns.swarmplot(data=pulsar["Brightness"], c="blue").set_title('Pulsar 6␣
↪Swarm plot of Emission Strength')
```

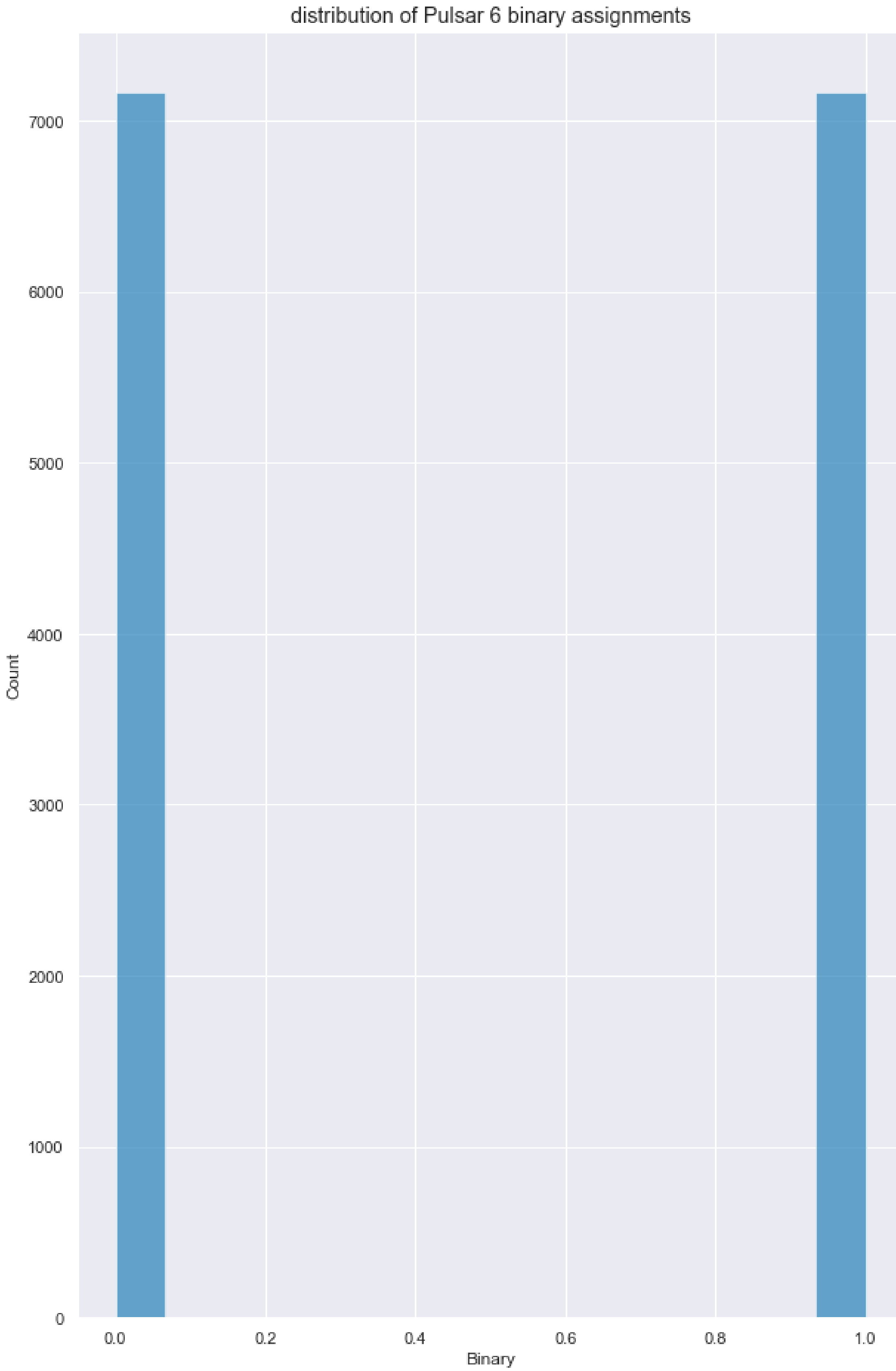
[ ]:
```
plt.figure(figsize=(10, 16))
with sns.axes_style('darkgrid'):
    sns.histplot(pulsar.Brightness)
plt.title("distribution of Pulsar 6 Brightness")
```

[ ]: Text(0.5, 1.0, 'distribution of Pulsar 6 Brightness')


distribution of Pulsar 6 Brightness
Count
Brightness
0
500
1000
1500
2000
0
2
4
6
8

[ ]:
```
plt.figure(figsize=(10, 16))
with sns.axes_style('darkgrid'):
    sns.histplot(pulsar.Binary)
plt.title("distribution of Pulsar 6 binary assignments")
```

[ ]:
```
Text(0.5, 1.0, 'distribution of Pulsar 6 binary assignments')
```



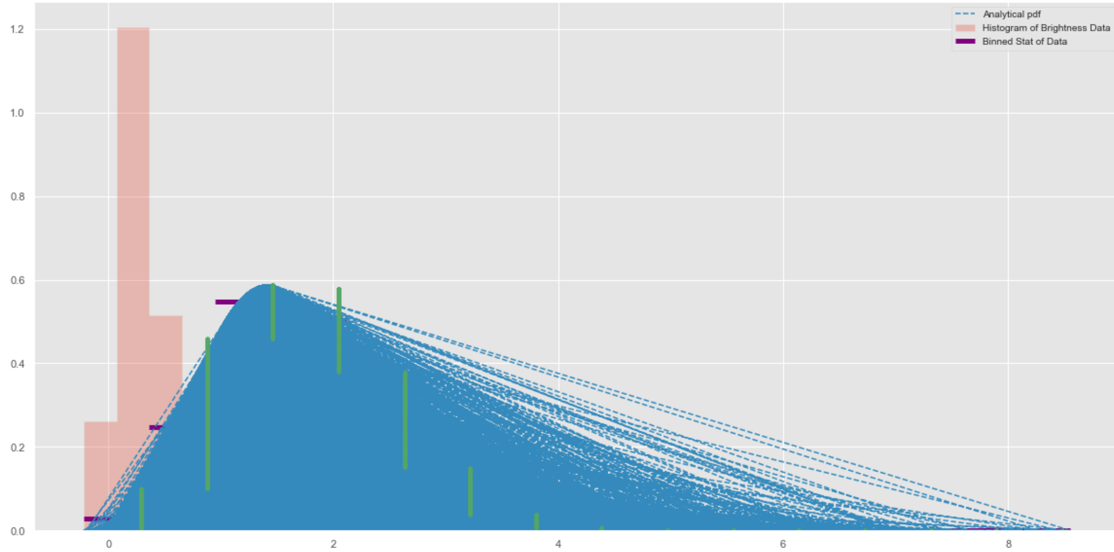
distribution of Pulsar 6 binary assignments
Count
Binary
0
1000
2000
3000
4000
5000
6000
7000
0.0
0.2
0.4
0.6
0.8
1.0

4 Rolling Medians, Rolling Means, Binned Medians and Binned Mean analysis.

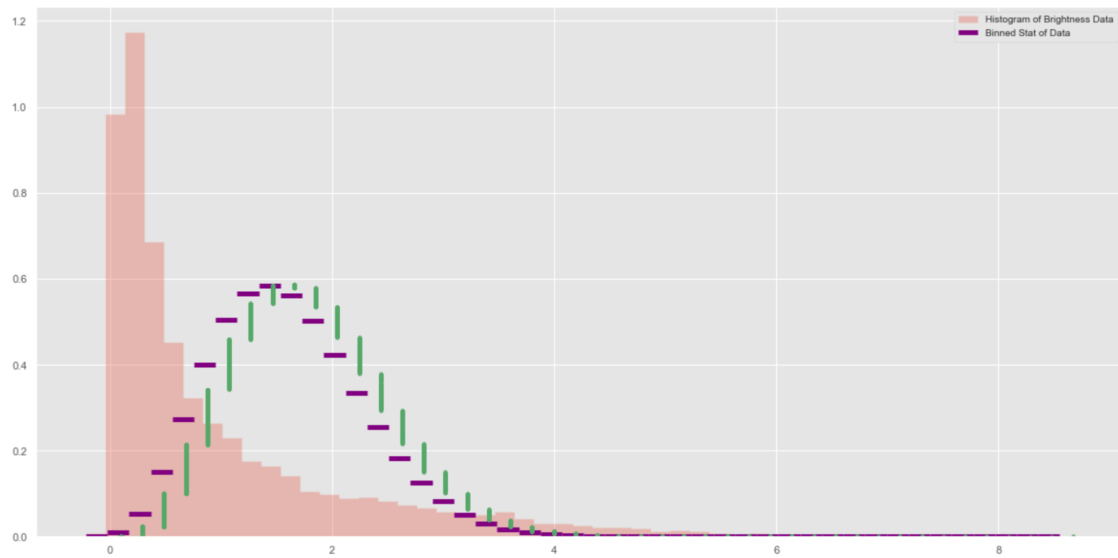
[ ]:
```
data = pulsar["Brightness"]
data
```

[ ]:
```
0         0.334330
1        -0.098659
2         0.123514
3         0.443923
4         1.590446
            …
14324    4.876881
14325    2.074136
14326    0.585504
14327    0.360930
14328    8.409811
Name: Brightness, Length: 14329, dtype: float64
```

[ ]:
```
dataPDF = stats.maxwell.pdf(data)
bin_means, bin_edges, binnumber = stats.binned_statistic(data, dataPDF,
        statistic='mean', bins=15)
bin_width = (bin_edges[1] - bin_edges[0])
bin_centers = bin_edges[1:] - bin_width/2

plt.figure(figsize=(20,10))
plt.hist(data, bins=30, density=True, histtype='stepfilled', alpha=0.3,␣
 ↪label='Histogram of Brightness Data')
plt.plot(data, dataPDF, '--', label = "Analytical pdf")
plt.hlines(bin_means, bin_edges[:-1], bin_edges[1:], colors='purple', lw=5,␣
 ↪label='Binned Stat of Data')
plt.plot((binnumber - 0.5) * bin_width, dataPDF, 'g.', alpha=0.5)
plt.legend(fontsize=10)
plt.show()
```



[ ]:
```
dataPDF = stats.maxwell.pdf(data)
bin_means, bin_edges, binnumber = stats.binned_statistic(data, dataPDF,
        statistic='mean', bins=45)
bin_width = (bin_edges[1] - bin_edges[0])
bin_centers = bin_edges[1:] - bin_width/2

plt.figure(figsize=(20,10))
plt.hist(data, bins=50, density=True, histtype='stepfilled', alpha=0.3,␣
 ↪label='Histogram of Brightness Data')
plt.hlines(bin_means, bin_edges[:-1], bin_edges[1:], colors='purple', lw=5,␣
 ↪label='Binned Stat of Data')
plt.plot((binnumber - 0.5) * bin_width, dataPDF, 'g.', alpha=0.5)
plt.legend(fontsize=10)
plt.show()
```

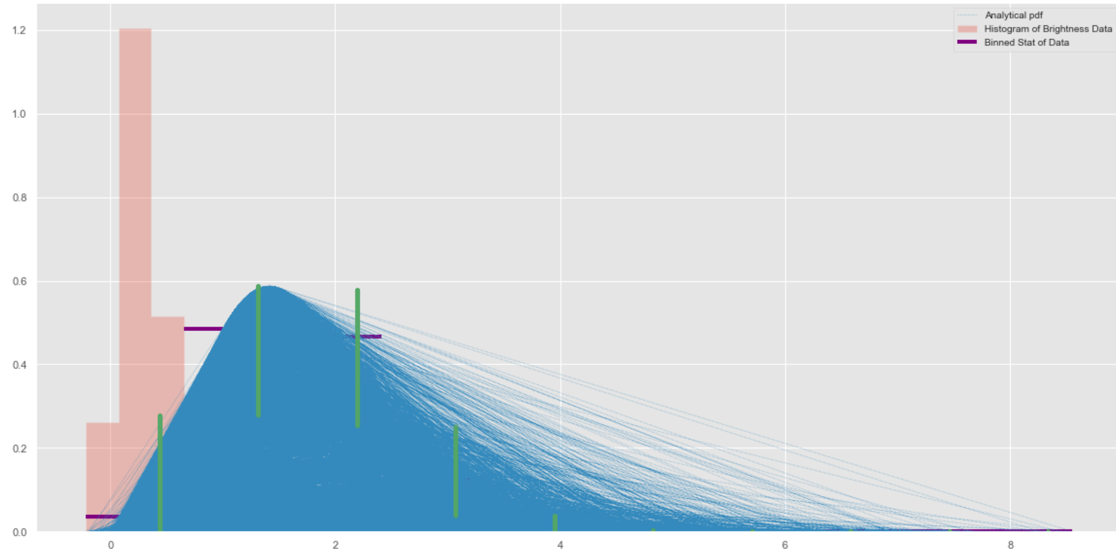


[ ]:
```
bin_means
```

[ ]:
```
array([0.00000000e+00, 8.81530427e-03, 5.38415730e-02, 1.49756107e-01,
       2.73125852e-01, 4.01123140e-01, 5.04761799e-01, 5.66191753e-01,
       5.84907585e-01, 5.61036295e-01, 5.01177831e-01, 4.21732083e-01,
       3.33612652e-01, 2.54679272e-01, 1.82840139e-01, 1.24506362e-01,
       8.24283627e-02, 5.00284899e-02, 3.03141668e-02, 1.69974463e-02,
       9.55908130e-03, 4.72589785e-03, 2.40750708e-03, 1.18099567e-03,
       5.06087771e-04, 2.28810393e-04, 1.06452122e-04, 4.29449863e-05,
       1.55640178e-05, 6.45344945e-06, 2.07944444e-06, 7.57196804e-07,
       2.31253715e-07, 6.97119673e-08, 2.43624651e-08, 7.51230054e-09,
       1.89486815e-09, 4.99721235e-10, 8.58589595e-11, 3.32495050e-11,
       7.97809520e-12, 3.47785011e-12, 3.20154700e-13, 8.29409902e-14,
       1.48398875e-14])
```

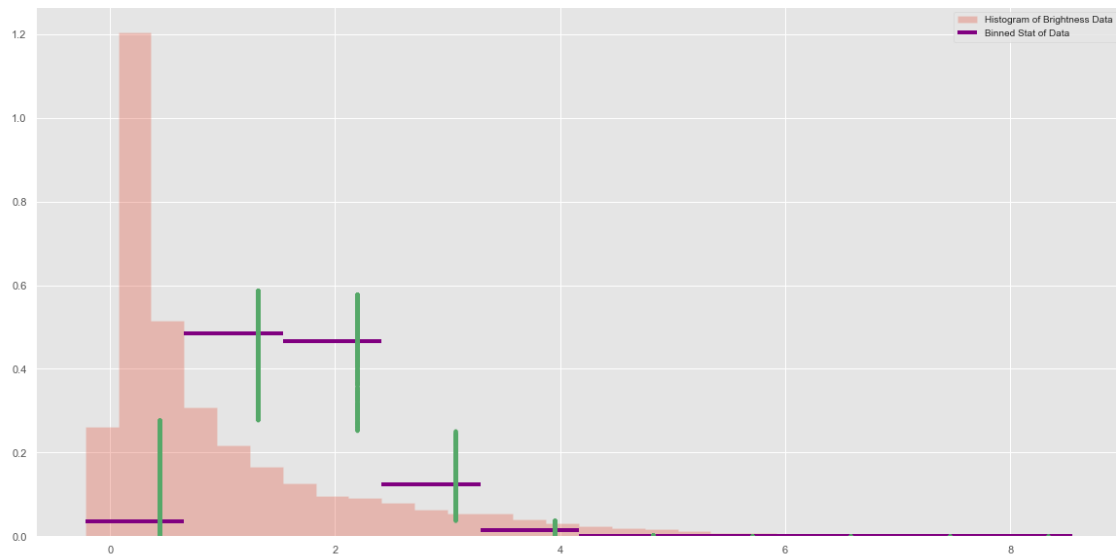
[ ]:
```
bin_median, bin_edges, binnumber = stats.binned_statistic(data, dataPDF,
        statistic='median', bins=10)
bin_width = (bin_edges[1] - bin_edges[0])
bin_centers = bin_edges[1:] - bin_width/2

plt.figure(figsize=(20,10))
plt.hist(data, bins=30, density=True, histtype='stepfilled', alpha=0.3,␣
 ↪label='Histogram of Brightness Data')
plt.plot(data, dataPDF, ':', label = "Analytical pdf", lw=0.5)
plt.hlines(bin_median, bin_edges[:-1], bin_edges[1:], colors='purple', lw=4,␣
 ↪label='Binned Stat of Data')
plt.plot((binnumber - 0.5) * bin_width, dataPDF, 'g.', alpha=0.5)
plt.legend(fontsize=10)
```

```
plt.show()
```

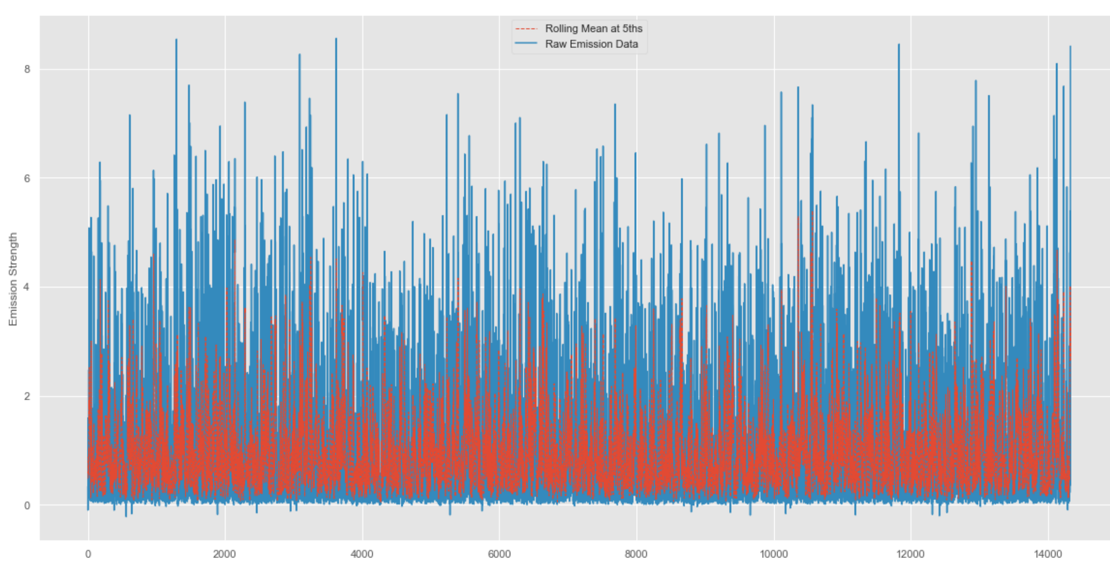


[ ]:

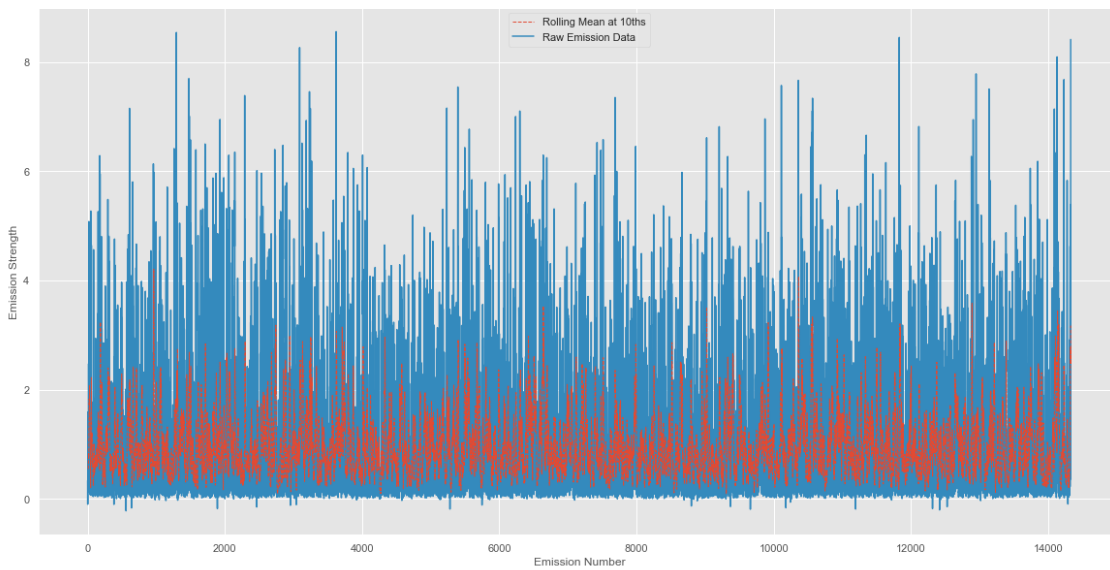
```
bin_median, bin_edges, binnumber = stats.binned_statistic(data, dataPDF,
        statistic='median', bins=10)
bin_width = (bin_edges[1] - bin_edges[0])
bin_centers = bin_edges[1:] - bin_width/2

plt.figure(figsize=(20,10))
plt.hist(data, bins=30, density=True, histtype='stepfilled', alpha=0.3,␣
 ↪label='Histogram of Brightness Data')
plt.hlines(bin_median, bin_edges[:-1], bin_edges[1:], colors='purple', lw=4,␣
 ↪label='Binned Stat of Data')
plt.plot((binnumber - 0.5) * bin_width, dataPDF, 'g.', alpha=0.5)
plt.legend(fontsize=10)
plt.show()
```



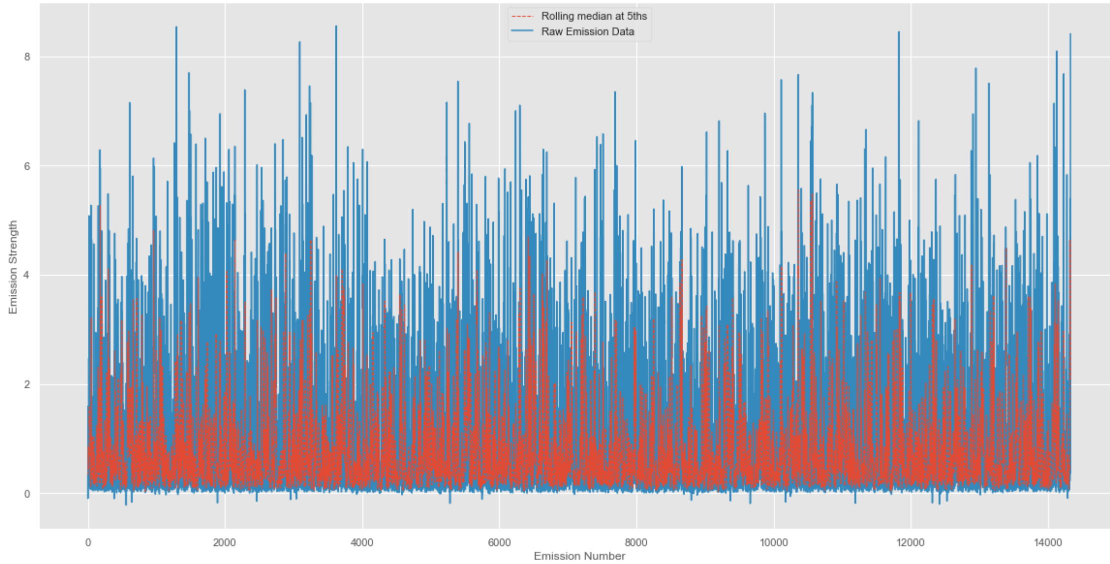
[ ]:
```
pulsar['RollingMeanEmissions5ths'] = pulsar["Brightness"].rolling(5).mean()

plt.figure(figsize=(20,10))
plt.plot(pulsar['RollingMeanEmissions5ths'], label="Rolling Mean at 5ths",␣
↪lw=1, linestyle='--', zorder=2)
plt.plot(pulsar['Brightness'], label= "Raw Emission Data", zorder=1)
plt.legend()
plt.ylabel('Emission Strength')
plt.xlabel('Emission Number')
plt.show()
```



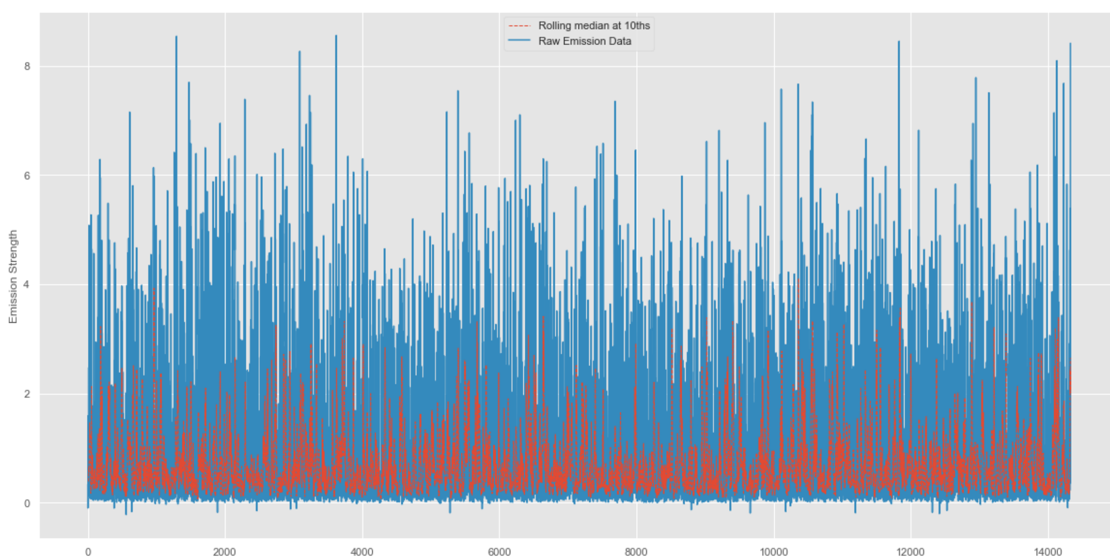
[ ]:
```
pulsar['RollingMeanEmissions10ths'] = pulsar["Brightness"].rolling(10).mean()

plt.figure(figsize=(20,10))
plt.plot(pulsar['RollingMeanEmissions10ths'], label="Rolling Mean at 10ths",␣
    ↪lw=1, linestyle='--', zorder=2)
plt.plot(pulsar['Brightness'], label= "Raw Emission Data", zorder=1)
plt.legend()
plt.ylabel('Emission Strength')
plt.xlabel('Emission Number')
plt.show()
```



[ ]:
```
pulsar['RollingMedianEmissions5ths'] = pulsar["Brightness"].rolling(5).median()

plt.figure(figsize=(20,10))
plt.plot(pulsar['RollingMedianEmissions5ths'], label="Rolling median at 5ths",␣
    ↪lw=1, linestyle='--', zorder=2)
plt.plot(pulsar['Brightness'], label= "Raw Emission Data", zorder=1)
plt.legend()
plt.ylabel('Emission Strength')
plt.xlabel('Emission Number')
plt.show()
```




```
[ ]: pulsar['RollingMedianEmissions10ths'] = pulsar["Brightness"].rolling(10).
     ↪median()

     plt.figure(figsize=(20,10))
     plt.plot(pulsar['RollingMedianEmissions10ths'], label="Rolling median at␣
     ↪10ths", lw=1, linestyle='--', zorder=2)
     plt.plot(pulsar['Brightness'], label= "Raw Emission Data", zorder=1)
     plt.legend()
     plt.ylabel('Emission Strength')
     plt.xlabel('Emission Number')
     plt.show()
```



```
[ ]: pulsar.head(25)
```

```
[ ]:    Pulse Number  Brightness  Uncertainty  Binary  RollingMeanEmissions5ths  \
    0              1    0.334330     0.015570       0                       NaN
    1              2   -0.098659     0.014051       0                       NaN
    2              3    0.123514     0.011901       0                       NaN
    3              4    0.443923     0.014365       0                       NaN
    4              5    1.590446     0.057785       1                  0.478711
    5              6    1.233848     0.018692       1                  0.658614
    6              7    0.857876     0.022208       1                  0.849921
    7              8    0.254255     0.018185       0                  0.876070
    8              9    0.292077     0.021672       0                  0.845700
    9             10    0.439929     0.046293       0                  0.615597
    10            11    0.824310     0.036243       1                  0.533689
    11            12    1.443460     0.088372       1                  0.650806
    12            13    0.127981     0.018070       0                  0.625551
    13            14    0.327896     0.012362       0                  0.632715
    14            15    2.473663     0.099205       1                  1.039462
    15            16    0.683800     0.049683       1                  1.011360
    16            17    0.744937     0.033909       1                  0.871656
    17            18    0.628764     0.032342       1                  0.971812
    18            19    5.077294     0.093078       1                  1.921692
    19            20    0.554981     0.025086       1                  1.537955
    20            21    1.006799     0.029068       1                  1.602555
    21            22    4.359872     0.091381       1                  2.325542
    22            23    1.576034     0.030928       1                  2.514996
    23            24    1.218368     0.067754       1                  1.743211
    24            25    1.377933     0.036103       1                  1.907801

        RollingMeanEmissions10ths  RollingMedianEmissions5ths  \
    0                         NaN                         NaN
    1                         NaN                         NaN
    2                         NaN                         NaN
    3                         NaN                         NaN
    4                         NaN                    0.334330
    5                         NaN                    0.443923
    6                         NaN                    0.857876
    7                         NaN                    0.857876
    8                         NaN                    0.857876
    9                    0.547154                    0.439929
    10                   0.596152                    0.439929
    11                   0.750364                    0.439929
    12                   0.750810                    0.439929
    13                   0.739208                    0.439929
```

```
14                     0.827529                      0.824310
15                     0.772525                      0.683800
16                     0.761231                      0.683800
17                     0.798682                      0.683800
18                     1.277203                      0.744937
19                     1.288709                      0.683800
20                     1.306958                      0.744937
21                     1.598599                      1.006799
22                     1.743404                      1.576034
23                     1.832451                      1.218368
24                     1.722878                      1.377933

    RollingMedianEmissions10ths
0                           NaN
1                           NaN
2                           NaN
3                           NaN
4                           NaN
5                           NaN
6                           NaN
7                           NaN
8                           NaN
9                      0.387130
10                     0.441926
11                     0.634116
12                     0.634116
13                     0.632119
14                     0.632119
15                     0.561864
16                     0.561864
17                     0.656282
18                     0.714369
19                     0.714369
20                     0.714369
21                     0.714369
22                     0.875868
23                     1.112583
24                     1.112583
```

4.1 Binary Classification

[ ]:
```
X = pulsar[['Brightness', 'Uncertainty']]
y = pulsar['Binary']
```

[ ]:
```
X.head()
```

```
[ ]:    Brightness  Uncertainty
     0    0.334330     0.015570
     1   -0.098659     0.014051
     2    0.123514     0.011901
     3    0.443923     0.014365
     4    1.590446     0.057785
```

```
[ ]: y.head()
```

```
[ ]: 0    0
     1    0
     2    0
     3    0
     4    1
     Name: Binary, dtype: int32
```

```
[ ]: from sklearn.model_selection import train_test_split

     X_train, X_test, y_train, y_test = train_test_split(X, y , test_size=0.20)
```

```
[ ]: from sklearn.preprocessing import StandardScaler

     train_scaler = StandardScaler()
     X_train = train_scaler.fit_transform(X_train)

     test_scaler = StandardScaler()
     X_test = test_scaler.fit_transform(X_test)
```

```
[ ]: model = LogisticRegression()

     model.fit(X_train, y_train)
```

```
[ ]: LogisticRegression()
```

```
[ ]: predictions = model.predict(X_test)
```

```
[ ]: from sklearn.metrics import confusion_matrix

     cm = confusion_matrix(y_test, predictions)

     TN, FP, FN, TP = confusion_matrix(y_test, predictions).ravel()

     print('True Positive(TP)  = ', TP)
     print('False Positive(FP) = ', FP)
     print('True Negative(TN)  = ', TN)
     print('False Negative(FN) = ', FN)
```

```
True Positive(TP)  =  1383
```

```
False Positive(FP) =  16
True Negative(TN)  =  1463
False Negative(FN) =  4
```

```
[ ]: accuracy =  (TP + TN) / (TP + FP + TN + FN)

     print("Accuracy of the model is ", accuracy)
```

```
Accuracy of the model is  0.9930216329378926
```

4.2 Bidirectional LSTM Model

```
[ ]: # making a list with the brightness and uncertainty values
     values_list = pulsar[['Brightness', 'Uncertainty']].values.tolist()
     values_list[:10]
```

```
[ ]: [[0.3343305, 0.01556971],
      [-0.09865925, 0.01405071],
      [0.1235136, 0.01190141],
      [0.4439226, 0.01436473],
      [1.590446, 0.05778468],
      [1.233848, 0.01869218],
      [0.8578762, 0.02220829],
      [0.2542552, 0.01818517],
      [0.2920765, 0.0216722],
      [0.4399285, 0.0462925]]
```

```
[ ]: from sklearn import preprocessing

     # normalizing the values
     values_list = preprocessing.normalize(values_list)
```

```
[ ]: # function for spliting a list in a format we can use in the model
     def split_list(blist, steps):
         X, y = list(), list()
         for i in range(len(blist)):
             end_ix = i + steps
             if end_ix > len(blist)-1:
                 break
             list_x, list_y = blist[i:end_ix], blist[end_ix][0]
             X.append(list_x)
             y.append(list_y)
         return array(X), array(y)
```

```
[ ]: # splitting the list
     X, y = split_list(values_list, 100)

     # reshaping the list to feed the model
```

```
X = X.reshape((X.shape[0], X.shape[1], 2))
```

[ ]:
```
# splitting the list into train and test sets
X_train, X_test, y_train, y_test = train_test_split(X, y , test_size=0.20)
```

[ ]:
```
X_train.shape
```

[ ]: (11383, 100, 2)

[ ]:
```
# setting the parameters for the lstm model and compiling it
model = Sequential()
model.add(Bidirectional(LSTM(50, activation='relu'), input_shape=(100, 2)))
model.add(Dense(25, activation='relu'))
model.add(Dense(12, activation='relu'))
model.add(Dense(6, activation='relu'))
model.add(Dense(1, activation='sigmoid'))
model.compile(loss='binary_crossentropy', optimizer='adam',␣
 ↪metrics=['accuracy'])
```

[ ]:
```
# training the model
history = model.fit(X_train, y_train, epochs=50, verbose=1,␣
 ↪batch_size=(int(X_train.shape[0]/50)))
```

```
Epoch 1/50
51/51 [==============================] - 13s 156ms/step - loss: 3.9091 -
accuracy: 0.0000e+00
Epoch 2/50
51/51 [==============================] - 7s 146ms/step - loss: 0.9053 -
accuracy: 0.0000e+00
Epoch 3/50
51/51 [==============================] - 8s 147ms/step - loss: 0.2776 -
accuracy: 0.0000e+00
Epoch 4/50
51/51 [==============================] - 7s 142ms/step - loss: 0.1853 -
accuracy: 0.0000e+00
Epoch 5/50
51/51 [==============================] - 7s 138ms/step - loss: 0.2861 -
accuracy: 0.0000e+00
Epoch 6/50
51/51 [==============================] - 7s 139ms/step - loss: 0.1150 -
accuracy: 0.0000e+00
Epoch 7/50
51/51 [==============================] - 7s 141ms/step - loss: 0.0976 -
accuracy: 0.0000e+00
Epoch 8/50
51/51 [==============================] - 7s 135ms/step - loss: 0.0847 -
accuracy: 0.0000e+00
Epoch 9/50
```

```
51/51 [==============================] - 7s 137ms/step - loss: 0.0782 -
accuracy: 0.0000e+00
Epoch 10/50
51/51 [==============================] - 7s 136ms/step - loss: 0.0748 -
accuracy: 0.0000e+00
Epoch 11/50
51/51 [==============================] - 7s 139ms/step - loss: 0.0731 -
accuracy: 0.0000e+00
Epoch 12/50
51/51 [==============================] - 7s 138ms/step - loss: 0.0722 -
accuracy: 0.0000e+00
Epoch 13/50
51/51 [==============================] - 7s 140ms/step - loss: 0.0718 -
accuracy: 0.0000e+00
Epoch 14/50
51/51 [==============================] - 7s 140ms/step - loss: 0.0716 -
accuracy: 0.0000e+00
Epoch 15/50
51/51 [==============================] - 7s 139ms/step - loss: 0.0716 -
accuracy: 0.0000e+00
Epoch 16/50
51/51 [==============================] - 7s 142ms/step - loss: 0.0715 -
accuracy: 0.0000e+00
Epoch 17/50
51/51 [==============================] - 7s 142ms/step - loss: 0.0715 -
accuracy: 0.0000e+00
Epoch 18/50
51/51 [==============================] - 7s 140ms/step - loss: 0.0715 -
accuracy: 0.0000e+00
Epoch 19/50
51/51 [==============================] - 7s 141ms/step - loss: 0.0715 -
accuracy: 0.0000e+00
Epoch 20/50
51/51 [==============================] - 7s 142ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 21/50
51/51 [==============================] - 7s 141ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 22/50
51/51 [==============================] - 7s 143ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 23/50
51/51 [==============================] - 7s 144ms/step - loss: 0.0715 -
accuracy: 0.0000e+00
Epoch 24/50
51/51 [==============================] - 7s 144ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 25/50
```

```
51/51 [==============================] - 7s 143ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 26/50
51/51 [==============================] - 7s 145ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 27/50
51/51 [==============================] - 7s 147ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 28/50
51/51 [==============================] - 7s 146ms/step - loss: 0.0715 -
accuracy: 0.0000e+00
Epoch 29/50
51/51 [==============================] - 8s 147ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 30/50
51/51 [==============================] - 7s 142ms/step - loss: 0.0715 -
accuracy: 0.0000e+00
Epoch 31/50
51/51 [==============================] - 7s 145ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 32/50
51/51 [==============================] - 7s 145ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 33/50
51/51 [==============================] - 8s 148ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 34/50
51/51 [==============================] - 8s 148ms/step - loss: 0.0715 -
accuracy: 0.0000e+00
Epoch 35/50
51/51 [==============================] - 7s 144ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 36/50
51/51 [==============================] - 8s 149ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 37/50
51/51 [==============================] - 7s 146ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 38/50
51/51 [==============================] - 8s 153ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 39/50
51/51 [==============================] - 8s 155ms/step - loss: 0.0715 -
accuracy: 0.0000e+00
Epoch 40/50
51/51 [==============================] - 7s 143ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 41/50
```

```
51/51 [==============================] - 7s 146ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 42/50
51/51 [==============================] - 8s 149ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 43/50
51/51 [==============================] - 8s 150ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 44/50
51/51 [==============================] - 7s 146ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 45/50
51/51 [==============================] - 7s 142ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 46/50
51/51 [==============================] - 7s 146ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 47/50
51/51 [==============================] - 7s 141ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 48/50
51/51 [==============================] - 8s 148ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 49/50
51/51 [==============================] - 8s 151ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
Epoch 50/50
51/51 [==============================] - 8s 147ms/step - loss: 0.0714 -
accuracy: 0.0000e+00
```

[ ]:
```
# predicting the y/brightness values for the test set
y_pred = model.predict(X_test, verbose=0)
y_pred[:10]
```

[ ]:
```
array([[0.9868081 ],
       [0.9869219 ],
       [0.9868876 ],
       [0.98695874],
       [0.9864262 ],
       [0.9870342 ],
       [0.9868975 ],
       [0.986964  ],
       [0.98687536],
       [0.98689437]], dtype=float32)
```

[ ]:
```
# evaluating the model
model.evaluate(X_test, y_test)
```

```
89/89 [==============================] - 2s 15ms/step - loss: 0.0738 - accuracy:
0.0000e+00
```

[ ]:
```
[0.07384754717350006, 0.0]
```

4.3 ML Evaluation.

4.3.1 Logistic Regression

Rewards no significant results for this type of analysis and is dropped for a LSTM attempt

4.3.2 Bidirectional LSTM

Loss is low so the model is performing well. But the accuracy is low therefore unable to obtain trend and therefore not rewarding any information. This means we cannot predict any of the values with confidence.

5 Preliminary runs test

5.0.1 Math Logic

$$Z = \frac{R - \tilde{R}}{s_R}$$

$$\tilde{R} = \frac{2_{n1n2}}{n1 + n2} + 1$$

$$s_R^2 = \frac{2_{n1n2}(2n1n2 - n1 - n2)}{(n1 + n2)^2(n1 + n2 - 1)}$$

link to resource: https://www.geeksforgeeks.org/runs-test-of-randomness-in-python/

$ Z_{critical} = 1.96 $ as the confidence interval level of 95% thus this is a 2 tailed test. If the probability as corrosponding to this confidence interval $ H_{null} $ will be rejected as it is not statistically significant as denoted by $|Z| > Z_{critical} $

There is also code attempting to change it from a z-score probability to a P-score for ease of understanding and clarity.

6 FUNCTION CODE FOR RUNS TEST

[ ]:
```python
binaryData1 = pulsar['Binary'].tolist()
print("pulsar6 original: ",binaryData1)
```

```
pulsar6 original:  [0, 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1,
1, 1, 0, 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0,
0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 1, 1, 0, 0,
1, 0, 1, 0, 0, 0, 1, 0, 0, 1, 0, 1, 0, 0, 0, 0, 1, 0, 0, 1, 0, 1, 0, 1, 0, 0, 1,
1, 1, 1, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1,
```

0, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0, 1, 0, 1, 1, 1,
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1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1, 0, 1, 0, 0, 1,
0, 0, 1, 0, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1,
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0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1,
0, 0, 0, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 1, 1, 0, 1, 1,
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1, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0,
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1, 0, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 0, 1, 0, 0, 1, 0, 1,
1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 1, 0, 0, 1, 1, 0, 1, 0, 0, 1, 1, 0,
0, 0, 0, 1, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 1, 1, 1,
1, 1, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0,
0, 0, 0, 1, 0, 1, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1]
```

7 Below we begin autocorrelation and autocovariance analysis

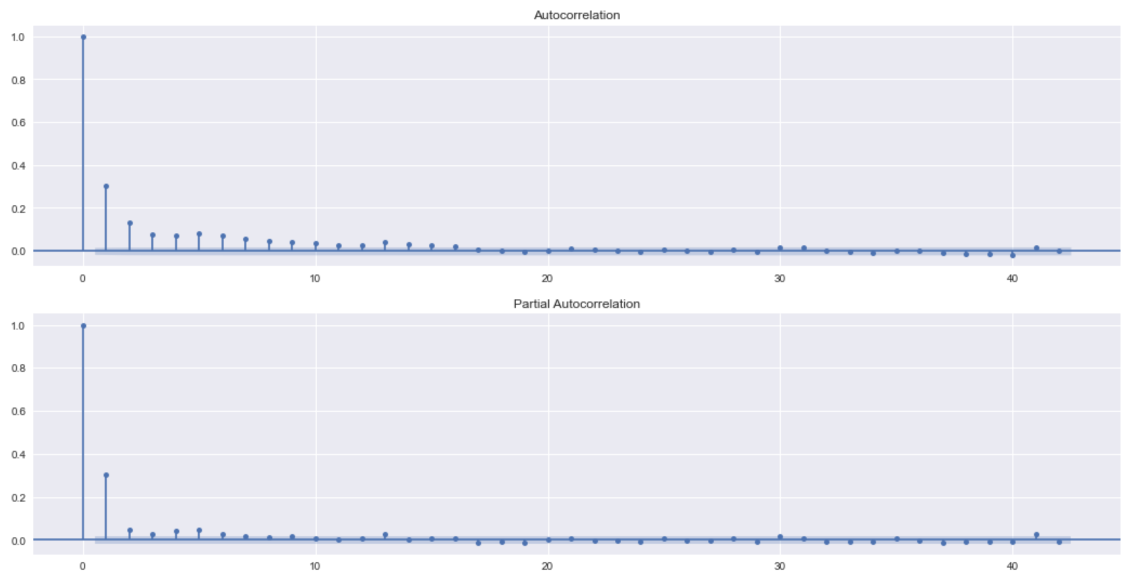
To get started with this I am playing around with guide from: https://towardsdatascience.com/a-step-by-step-guide-to-calculating-autocorrelation-and-partial-autocorrelation-8c4342b784e8

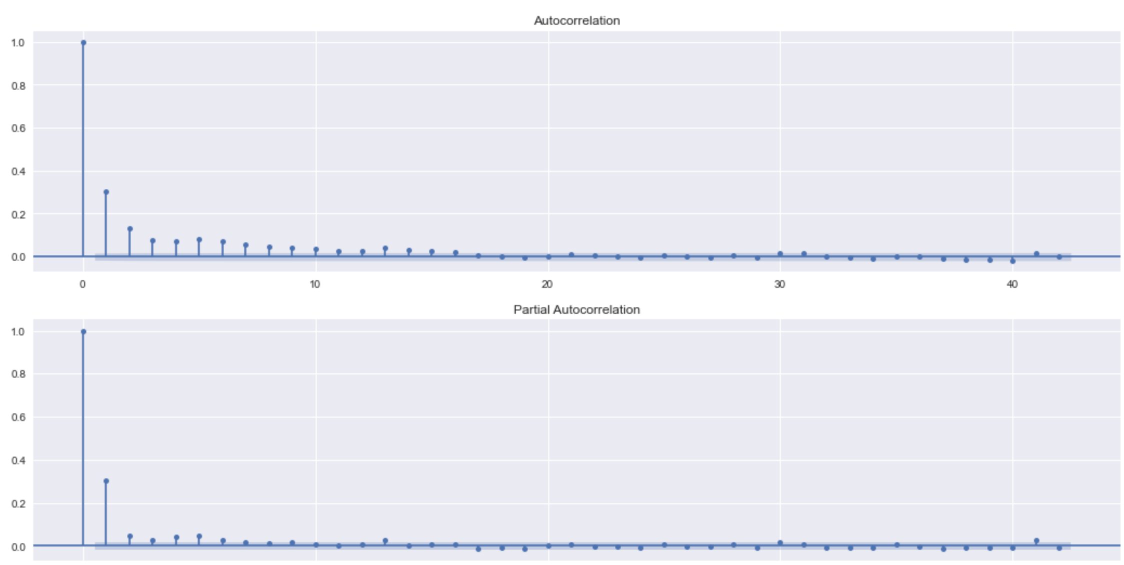
[ ]:
```
plt.style.use("seaborn")
plt.rcParams["figure.figsize"] = (18, 9)

fig, ax = plt.subplots(2,1)

plot_acf(pulsar['Brightness'], ax=ax[0])
plot_pacf(pulsar['Brightness'], ax=ax[1], method="ols")
```

[ ]:





[ ]:
```
acf(pulsar['Brightness'], nlags=10)
```

```
C:\Users\tajki\anaconda3\lib\site-packages\statsmodels\tsa\stattools.py:667:
FutureWarning: fft=True will become the default after the release of the 0.12
release of statsmodels. To suppress this warning, explicitly set fft=False.
  warnings.warn(
```

[ ]:
```
array([1.        , 0.30152047, 0.13254511, 0.07716124, 0.07364129,
       0.08096058, 0.07046427, 0.05556536, 0.0436438 , 0.04277081,
       0.03660132])
```

[ ]:
```
acfpulsar = pd.DataFrame()
for lag in range(0,11):
    acfpulsar[f"B_lag_{lag}"] = pulsar['Brightness'].shift(lag)


acfpulsar
```

[ ]:
```
        B_lag_0   B_lag_1   B_lag_2   B_lag_3   B_lag_4   B_lag_5   B_lag_6  \
0      0.334330       NaN       NaN       NaN       NaN       NaN       NaN
1     -0.098659  0.334330       NaN       NaN       NaN       NaN       NaN
2      0.123514 -0.098659  0.334330       NaN       NaN       NaN       NaN
3      0.443923  0.123514 -0.098659  0.334330       NaN       NaN       NaN
4      1.590446  0.443923  0.123514 -0.098659  0.334330       NaN       NaN
…           …        …        …        …        …        …        …
14324  4.876881  5.386421  3.224787  1.953645  4.624813  0.225158  1.502603
14325  2.074136  4.876881  5.386421  3.224787  1.953645  4.624813  0.225158
14326  0.585504  2.074136  4.876881  5.386421  3.224787  1.953645  4.624813
14327  0.360930  0.585504  2.074136  4.876881  5.386421  3.224787  1.953645
14328  8.409811  0.360930  0.585504  2.074136  4.876881  5.386421  3.224787

        B_lag_7   B_lag_8   B_lag_9  B_lag_10
0           NaN       NaN       NaN       NaN
1           NaN       NaN       NaN       NaN
2           NaN       NaN       NaN       NaN
3           NaN       NaN       NaN       NaN
4           NaN       NaN       NaN       NaN
…           …        …        …        …
14324  1.389349  1.592995  2.913151  0.181665
14325  1.502603  1.389349  1.592995  2.913151
14326  0.225158  1.502603  1.389349  1.592995
14327  4.624813  0.225158  1.502603  1.389349
14328  1.953645  4.624813  0.225158  1.502603

[14329 rows x 11 columns]
```

```
[ ]: acfpulsar.corr()["B_lag_0"].values
```

```
[ ]: array([1.        , 0.30191886, 0.13272532, 0.07726788, 0.07374568,
            0.08110522, 0.07062283, 0.0556971 , 0.04374889, 0.04288793,
            0.0367024 ])
```

7.0.1 Getting every 5th as per the auto correlation

7.0.2 Creating a new set of discrete 100 sets and examining them specifically

7.0.3 Further Random testing to move into extensive testing

Getting every 5th as per the auto correlation

```
[ ]: held5ths = pulsar[pulsar.index % 5 == 0]
     held5ths
```

```
[ ]:        Pulse Number  Brightness  Uncertainty  Binary  \
     0                 1    0.334330     0.015570       0
     5                 6    1.233848     0.018692       1
     10               11    0.824310     0.036243       1
     15               16    0.683800     0.049683       1
     20               21    1.006799     0.029068       1
     …               …         …           …      …
     14305         14306    0.081548     0.011737       0
     14310         14311    0.060433     0.011708       0
     14315         14316    2.913151     0.089312       1
     14320         14321    4.624813     0.095899       1
     14325         14326    2.074136     0.080444       1

            RollingMeanEmissions5ths  RollingMeanEmissions10ths  \
     0                           NaN                        NaN
     5                      0.658614                        NaN
     10                     0.533689                   0.596152
     15                     1.011360                   0.772525
     20                     1.602555                   1.306958
     …                           …                          …
     14305                  0.150069                   0.206964
     14310                  0.624411                   0.387240
     14315                  1.018175                   0.821293
     14320                  1.866984                   1.442579
     14325                  3.503174                   2.685079

            RollingMedianEmissions5ths  RollingMedianEmissions10ths
     0                             NaN                          NaN
     5                        0.443923                          NaN
     10                       0.439929                     0.441926
     15                       0.683800                     0.561864
     20                       0.744937                     0.714369
```

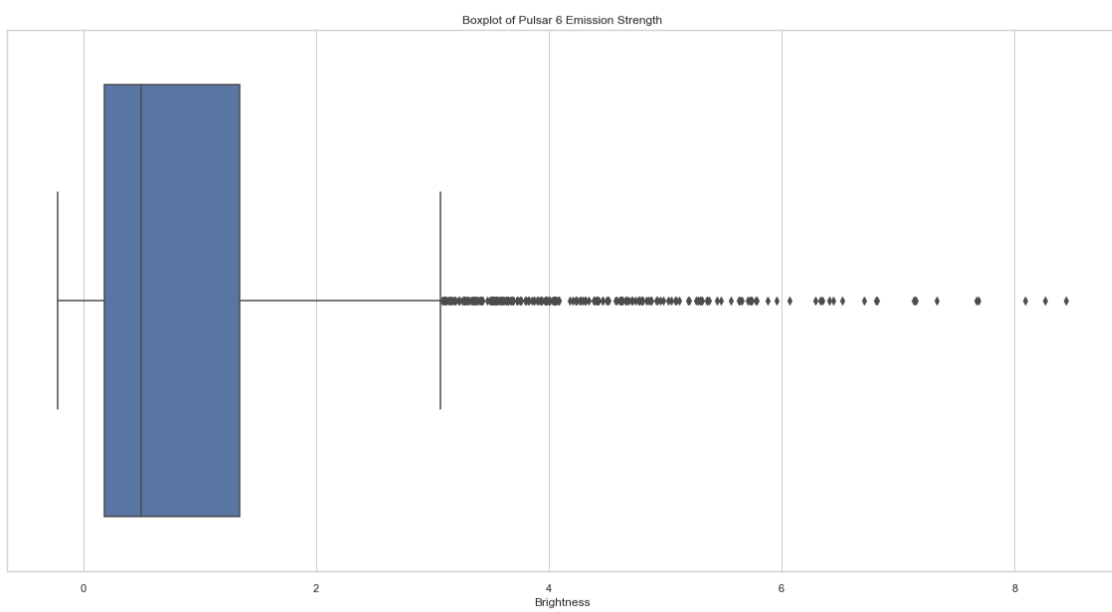
```
…                         …                          …
14305                     0.081548                   0.133974
14310                     0.374685                   0.178749
14315                     0.496700                   0.469194
14320                     1.502603                   1.223510
14325                     3.224787                   2.013891

[2866 rows x 8 columns]
```

[ ]:
```
medianheld5ths = held5ths["Brightness"].median()
medianheld5ths
```

[ ]: 0.49492415

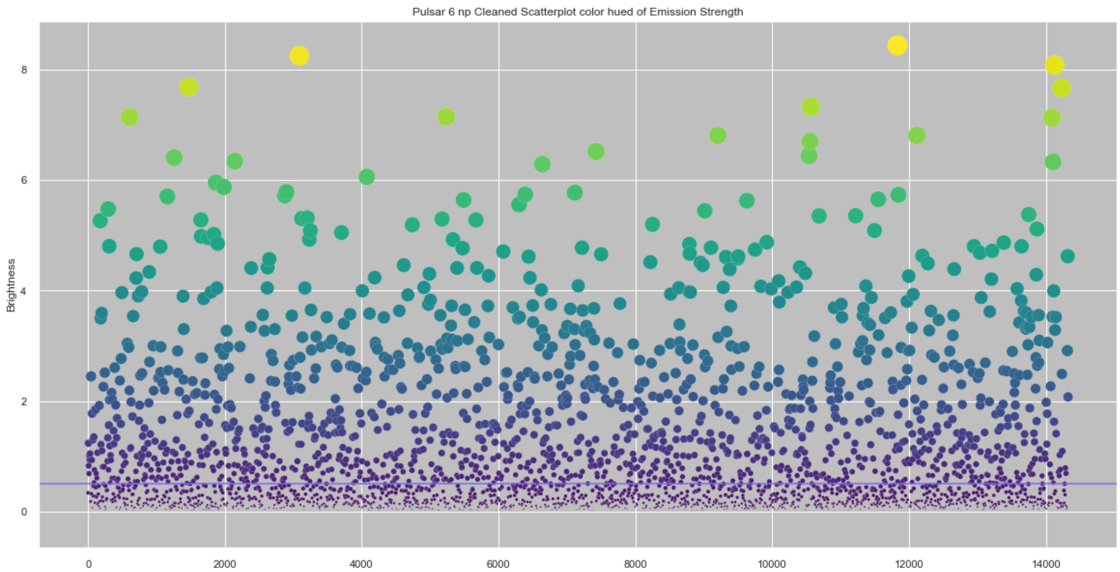
[ ]:
```
plt.figure(figsize=(20,10))
sns.set_theme(style="whitegrid")
ax = sns.boxplot(x=held5ths["Brightness"]).set_title("Boxplot of Pulsar 6␣
↪Emission Strength")
```



[ ]:
```
plt.figure(figsize=(20,10))
sns.set_style("darkgrid", {"axes.facecolor": ".75"})
strength = held5ths.Brightness.values
ax = sns.scatterplot(data=held5ths["Brightness"], s= strength*50, c=strength,␣
↪cmap="viridis", marker="o").set_title('Pulsar 6 np Cleaned Scatterplot color␣
↪hued of Emission Strength')
ax = plt.axhline( y=0.49492415, ls='-',c='mediumslateblue')
```

C:\Users\tajki\anaconda3\lib\site-packages\matplotlib\collections.py:1003:

```
RuntimeWarning: invalid value encountered in sqrt
  scale = np.sqrt(self._sizes) * dpi / 72.0 * self._factor
```




```
[ ]: #plt.figure(figsize=(20,10))
     #sns.set_style("darkgrid", {"axes.facecolor": ".75"})
     #strength = held5ths.Brightness.values
     #ax = plt.axhline( y=0.49492415, ls='-',c='mediumslateblue')
     #ax = sns.swarmplot(data=held5ths["Brightness"], c="blue").set_title('Pulsar 6␣
      ↪Swarm plot of Emission Strength')
```

```
[ ]: print(len(held5ths[(held5ths.Brightness > 0.49492415)]))
     print(len(held5ths[(held5ths.Brightness < 0.49492415)]))
```

```
1433
1433
```

Randomness testing

```
[ ]: np.savetxt(r'every5thbinarypulsar2.txt', held5ths.Binary, fmt='%d',␣
      ↪delimiter='')
     np.savetxt(r'allpulsar2.txt', pulsar.Binary, fmt='%d', delimiter='')
```

```
[ ]: pulsar.Binary
```

```
[ ]: 0        0
     1        0
     2        0
     3        0
     4        1
```

```
         ..
14324    1
14325    1
14326    1
14327    0
14328    1
Name: Binary, Length: 14329, dtype: int32
```