Python Final Project for analysis of Light Curve

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I. CODE-MAIN.PY

Listing 1: main.py code

```python
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from scipy.stats import norm
from statsmodels.graphics.tsaplots import plot_acf
from statsmodels.tsa.seasonal import seasonal_decompose
from scipy.interpolate import interp1d
import logging


######### BASE CLASS ##############

class TimeSeriesAnalyzer:
def __init__(self, filename, energy_range, title):
    self.filename = filename
    self.energy_range = energy_range
    self.title = title
    self.data = None
    self.logger = logging.getLogger(__name__)

def read_data(self):
    """Read the data from a text file into a pandas DataFrame."""
    try:
        self.data = pd.read_csv(self.filename, sep='\t', skiprows=4, names=['Tstart (s
        )', 'Counts/s'])
        self.logger.info("Data loaded successfully.")
    except FileNotFoundError:
        self.logger.error("File not found.")
    except Exception as e:
        self.logger.error(f"Error loading data: {e}")

def clean_data(self):
    """Clean the data by handling missing values, outliers, and adjusting data types.
    """
    pass  # Placeholder for data cleaning

def display_data(self):
    """Display the data using various types of plots."""
    if self.data is not None:
        # Time series plot
        plt.figure(figsize=(10, 6))
        plt.plot(self.data['Tstart (s)'], self.data['Counts/s'], label='Time Series')
        plt.xlabel('Time (s)')
        plt.ylabel('Counts/s')
        plt.title('Time Series Plot')
        plt.legend()
        plt.grid(True)
        plt.show()

```

```python
            # Scatter plot
            plt.figure(figsize=(8, 6))
            plt.scatter(self.data['Tstart (s)'], self.data['Counts/s'], marker='.', color='blue', label='Scatter Plot')
            plt.xlabel('Time (s)')
            plt.ylabel('Counts/s')
            plt.title('Scatter Plot')
            plt.legend()
            plt.grid(True)
            plt.show()

            # Histogram

            # Histogram with fitted normal distribution line
            plt.figure(figsize=(8, 6))
            plt.hist(self.data['Counts/s'], bins=20, color='green', alpha=0.7, density=True, label='Histogram')

            # Fit a normal distribution to the data
            mu, sigma = self.data['Counts/s'].mean(), self.data['Counts/s'].std()
            xmin, xmax = plt.xlim()
            x = np.linspace(xmin, xmax, 100)
            p = norm.pdf(x, mu, sigma)
            plt.plot(x, p, 'k', linewidth=2, label='Fitted Normal Distribution')

            plt.xlabel('Counts/s')
            plt.ylabel('Frequency')
            plt.title('Histogram with Fitted Normal Distribution')
            plt.legend()
            plt.grid(True)
            plt.show()

            self.logger.info("Data displayed.")
        else:
            self.logger.warning("No data to display.")

    def apply_operations(self):
        """Apply mathematical operations or perform statistical analyses."""
        pass  # Placeholder for operations or analyses



    ############### SUB CLASS ##########################

class DetrendingAnalyzer(TimeSeriesAnalyzer):
    def __init__(self, filename, energy_range, title):
        super().__init__(filename, energy_range, title)

    def detrend_rescale(self):
        """Detrend the data by subtracting the mean and rescale it to fit within the interval [-1, 1]."""
        if self.data is not None:
            try:
                self.data['Counts/s'] -= self.data['Counts/s'].mean()
                self.data['Counts/s'] /= max(abs(self.data['Counts/s']))
                self.logger.info("Data detrended and rescaled.")
            except Exception as e:
                self.logger.error(f"Error detrending data: {e}")
        else:
            self.logger.warning("No data to detrend.")

    def plot_detrended_time_series(self):
```

```
        """Plot the detrended time series to visually inspect the removal of trends."""
        if self.data is not None:
            plt.figure(figsize=(10, 6))
            plt.plot(self.data['Tstart (s)'], self.data['Counts/s'], label='Detrended Counts/s')
            plt.xlabel('Time (s)')
            plt.ylabel('Detrended Counts/s')
            plt.title('Detrended Time Series')
            plt.legend()
            plt.grid(True)
            plt.show()
            self.logger.info("Detrended time series plotted.")
        else:
            self.logger.warning("No data to plot.")

    def plot_acf_detrended(self):
        """Calculate and plot the autocorrelation function (ACF) to assess stationarity."""
        if self.data is not None:
            try:
                plot_acf(self.data['Counts/s'], lags=50)
                plt.title('Autocorrelation Function (ACF) of Detrended Series')
                plt.xlabel('Lag')
                plt.ylabel('ACF')
                plt.show()
                self.logger.info("Autocorrelation function of detrended series plotted.")
            except Exception as e:
                self.logger.error(f"Error plotting autocorrelation function: {e}")
        else:
            self.logger.warning("No data to plot.")

    def time_series_decomposition(self):
        """Perform time series decomposition to separate trend, seasonal, and residual components."""
        if self.data is not None:
            try:
                result = seasonal_decompose(self.data['Counts/s'], model='additive', period=100)
                result.plot()
                plt.suptitle('Time Series Decomposition')
                plt.show()
                self.logger.info("Time series decomposition performed.")
            except Exception as e:
                self.logger.error(f"Error performing time series decomposition: {e}")
        else:
            self.logger.warning("No data to decompose.")

class InterpolationAnalyzer(TimeSeriesAnalyzer):
    def __init__(self, filename, energy_range, title):
        super().__init__(filename, energy_range, title)

    def interpolate_data(self, method='linear'):
        """Perform interpolation on the time series data."""
        if self.data is not None:
            try:
                # Define interpolation function
                interp_func = interp1d(self.data['Tstart (s)'], self.data['Counts/s'], kind=method)
                # Generate interpolated data
                interpolated_counts = interp_func(self.data['Tstart (s)'])
                # Update DataFrame with interpolated values
                self.data['Interpolated Counts/s'] = interpolated_counts
```

```
                self.logger.info(f"Data interpolated using {method} method.")
            except Exception as e:
                self.logger.error(f"Error interpolating data: {e}")
        else:
            self.logger.warning("No data to interpolate.")

    def plot_interpolated_time_series(self):
        """Plot the original and interpolated time series."""
        if self.data is not None:
            plt.figure(figsize=(10, 6))
            plt.plot(self.data['Tstart (s)'], self.data['Counts/s'], label='Original Time Series', color='blue')
            plt.plot(self.data['Tstart (s)'], self.data['Interpolated Counts/s'], label='Interpolated Time Series', color='red', linestyle='--')
            plt.xlabel('Time (s)')
            plt.ylabel('Counts/s')
            plt.title('Original vs Interpolated Time Series')
            plt.legend()
            plt.grid(True)
            plt.show()
            self.logger.info("Interpolated time series plotted.")
        else:
            self.logger.warning("No data to plot.")

class CumulativeSummationAnalyzer(TimeSeriesAnalyzer):
    def __init__(self, filename, energy_range, title):
        super().__init__(filename, energy_range, title)

    def calculate_cumulative_sum(self):
        """Calculate the cumulative sum of the counts."""
        if self.data is not None:
            try:
                self.data['Cumulative Sum'] = self.data['Counts/s'].cumsum()
                self.logger.info("Cumulative sum calculated.")
            except Exception as e:
                self.logger.error(f"Error calculating cumulative sum: {e}")
        else:
            self.logger.warning("No data to calculate cumulative sum.")

    def plot_cumulative_sum(self):
        """Plot the cumulative sum."""
        if self.data is not None:
            plt.figure(figsize=(10, 6))
            plt.plot(self.data['Tstart (s)'], self.data['Cumulative Sum'], label='Cumulative Sum', color='green')
            plt.xlabel('Time (s)')
            plt.ylabel('Cumulative Sum')
            plt.title('Cumulative Sum Plot')
            plt.legend()
            plt.grid(True)
            plt.show()
            self.logger.info("Cumulative sum plot generated.")
        else:
            self.logger.warning("No data to plot.")

    def find_t90(self):
        """Find the T_90 duration for the GRB event."""
        if self.data is not None:
            try:
                # Sort the data by time
                sorted_data = self.data.sort_values(by='Tstart (s)')

```

```
            # Calculate cumulative sum
            sorted_data['Cumulative Sum'] = sorted_data['Counts/s'].cumsum()

            # Calculate total counts
            total_counts = sorted_data['Counts/s'].sum()

            # Find the index when cumulative sum reaches 5% and 95% of total counts
            start_index = (sorted_data['Cumulative Sum'].cumsum() >= 0.05 *
                total_counts).idxmax()
            end_index = (sorted_data['Cumulative Sum'].cumsum() >= 0.95 * total_counts
                ).idxmax()

            # Get the times corresponding to the initial and final indices
            initial_time = sorted_data.loc[start_index, 'Tstart (s)']
            final_time = sorted_data.loc[end_index, 'Tstart (s)']

            self.logger.info(f"T_90: {initial_time} to {final_time} seconds")
            return initial_time, final_time
        except Exception as e:
            self.logger.error(f"Error finding T_90: {e}")
    else:
        self.logger.warning("No data to find T_90.")
```

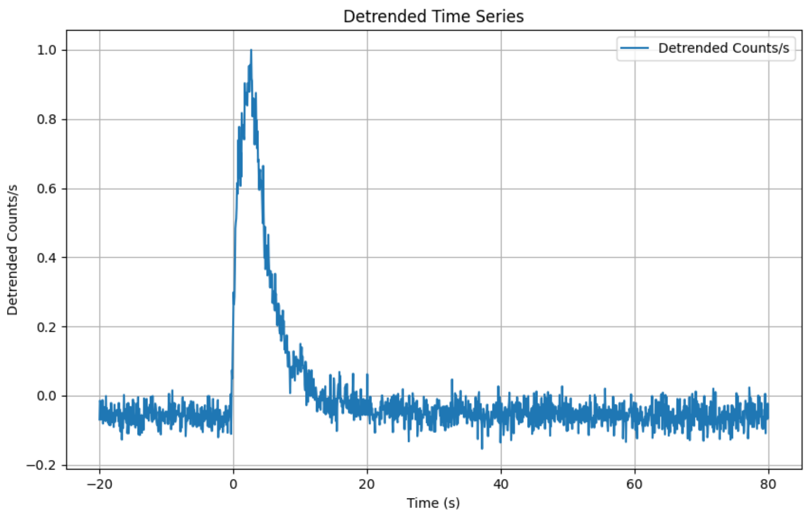
Listing 2: presentation.py code

```

    import main
import logging

# System MacOS Python Vesion: 3.9.6
# matplotlib                3.7.0
# matplotlib-inline         0.1.6
# numpy                     1.23.4
# pandas                    2.2.2
# scipy                     1.10.0
# statsmodels               0.14.2

# Example usage:
filename = "data.txt"
energy_range = "50-300 KeV"
title = "Light Curve for Fermi Event BN081224887"

# Set up logging
logging.basicConfig(level=logging.INFO)

# Create instances of subclasses
detrending_analyzer = main.DetrendingAnalyzer(filename, energy_range, title)
detrending_analyzer.read_data()

detrending_analyzer.detrend_rescale()

detrending_analyzer.plot_detrended_time_series()

detrending_analyzer.plot_acf_detrended()

detrending_analyzer.time_series_decomposition()

detrending_analyzer.display_data()
```

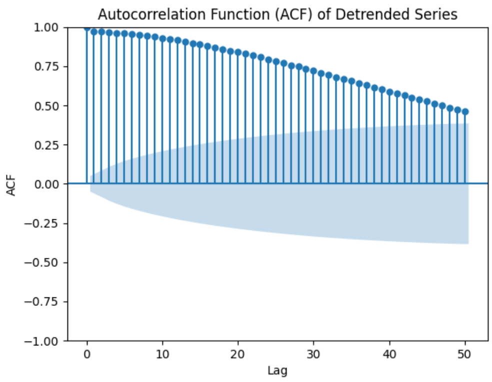
```python
# Create instances of the InterpolationAnalyzer and CumulativeSummationAnalyzer
    subclasses
interpolation_analyzer = main.InterpolationAnalyzer(filename, energy_range, title)
cumulative_summation_analyzer = main.CumulativeSummationAnalyzer(filename,
    energy_range, title)

# Read data
interpolation_analyzer.read_data()
cumulative_summation_analyzer.read_data()

# Interpolate data using linear interpolation
interpolation_analyzer.interpolate_data(method='linear')

# Calculate cumulative sum
cumulative_summation_analyzer.calculate_cumulative_sum()

# Plot interpolated time series
interpolation_analyzer.plot_interpolated_time_series()

# Plot cumulative sum
cumulative_summation_analyzer.plot_cumulative_sum()
```

II. RESULT

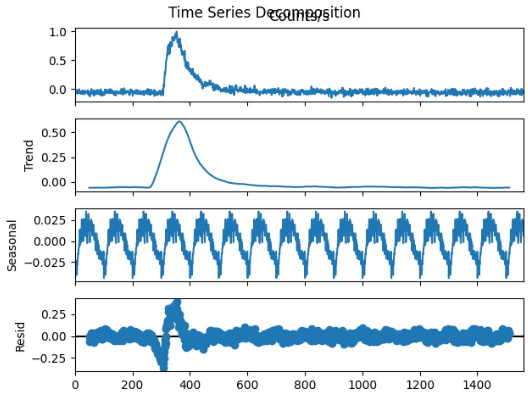
We firstly plot the intensity with time series for light curve.



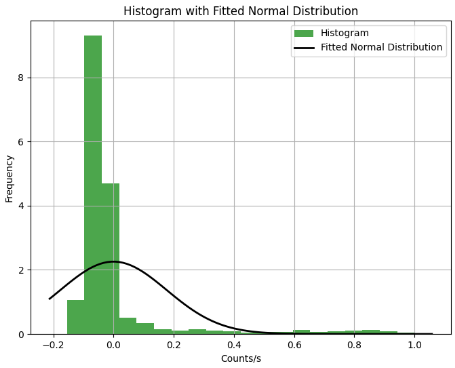
Then we can do the following analysis for this light curve.



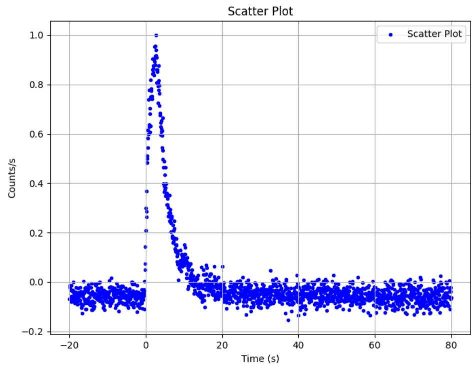
(a) Diagram for ACF



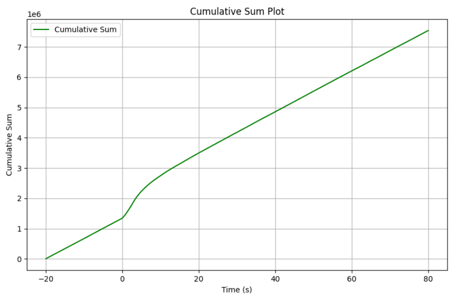
(b) Diagram for decomposition



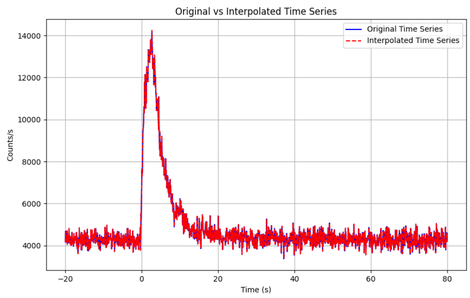
(c) Diagram for light curve's histogram



(d) Diagram for light curve's scatter plot



(e) Cumulative plot



(f) Interpolated Plot

III. APPENDIX FILE

A. Log.txt

Listing 3: log.txt

```
2024-05-05 20:02:52,699 - INFO - Data loaded successfully.
2024-05-05 20:02:52,701 - INFO - Data detrended and rescaled.
2024-05-05 20:02:54,417 - INFO - Detrended time series plotted.
2024-05-05 20:02:55,597 - INFO - Autocorrelation function of detrended series plotted.
2024-05-05 20:02:56,664 - INFO - Time series decomposition performed.
2024-05-05 20:02:59,331 - INFO - Data displayed.
2024-05-05 20:02:59,335 - INFO - Data loaded successfully.
```

```
2024-05-05 20:02:59,336 - INFO - Data loaded successfully.
2024-05-05 20:02:59,338 - INFO - Data interpolated using linear method.
2024-05-05 20:02:59,338 - INFO - Cumulative sum calculated.
2024-05-05 20:03:00,497 - INFO - Interpolated time series plotted.
2024-05-05 20:03:01,481 - INFO - Cumulative sum plot generated.
```