



PANDAS FOUNDATIONS

pandas Foundations



What is pandas?

- Python library for data analysis
- High-performance containers for data analysis
- Data structures with a lot of functionality
 - Meaningful labels
 - Time series functionality
 - Handling missing data
 - Relational operations

What you will learn

- How to work with pandas
 - Data import & export in various formats
- Exploratory Data Analysis using pandas
 - Statistical & graphical methods
- Using pandas to model *time series*
 - Time indexes, resampling



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**See you in
the course!**



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Review of pandas DataFrames



pandas DataFrames

- Example: DataFrame of Apple Stock data

Date	Open	High	Low	Close	Volume	Adj Close
2014-09-16	99.80	101.26	98.89	100.86	66818200	100.86
2014-09-15	102.81	103.05	101.44	101.63	61216500	101.63
2014-09-12	101.21	102.19	101.08	101.66	62626100	101.66
...



Indexes and columns

```
In [1]: import pandas as pd
```

```
In [2]: type(AAPL)
```

```
Out[2]: pandas.core.frame.DataFrame
```

```
In [3]: AAPL.shape
```

```
Out[3]: (8514, 6)
```

```
In [4]: AAPL.columns
```

```
Out[4]:
```

```
Index(['Open', 'High', 'Low', 'Close', 'Volume', 'Adj Close'],  
      dtype='object')
```

```
In [5]: type(AAPL.columns)
```

```
Out[5]: pandas.indexes.base.Index
```



Indexes and columns

```
In [6]: AAPL.index
```

```
Out[6]:
```

```
DatetimeIndex(['2014-09-16', '2014-09-15', '2014-09-12',  
               '2014-09-11', '2014-09-10', '2014-09-09',  
               '2014-09-08', '2014-09-05', '2014-09-04',  
               '2014-09-03',  
               ...  
               '1980-12-26', '1980-12-24', '1980-12-23',  
               '1980-12-22', '1980-12-19', '1980-12-18',  
               '1980-12-17', '1980-12-16', '1980-12-15',  
               '1980-12-12'],  
              dtype='datetime64[ns]', name='Date', length=8514,  
              freq=None)
```

```
In [7]: type(AAPL.index)
```

```
Out[7]: pandas.tseries.index.DatetimeIndex
```



Slicing

```
In [8]: AAPL.iloc[:5,:]
```

```
Out[8]:
```

	Open	High	Low	Close	Volume	Adj Close
Date						
2014-09-16	99.80	101.26	98.89	100.86	66818200	100.86
2014-09-15	102.81	103.05	101.44	101.63	61216500	101.63
2014-09-12	101.21	102.19	101.08	101.66	62626100	101.66
2014-09-11	100.41	101.44	99.62	101.43	62353100	101.43
2014-09-10	98.01	101.11	97.76	101.00	100741900	101.00

```
In [9]: AAPL.iloc[-5:,:]
```

```
Out[9]:
```

	Open	High	Low	Close	Volume	Adj Close
Date						
1980-12-18	26.63	26.75	26.63	26.63	18362400	0.41
1980-12-17	25.87	26.00	25.87	25.87	21610400	0.40
1980-12-16	25.37	25.37	25.25	25.25	26432000	0.39
1980-12-15	27.38	27.38	27.25	27.25	43971200	0.42
1980-12-12	28.75	28.87	28.75	28.75	117258400	0.45



head()

```
In [10]: AAPL.head(5)
```

```
Out[10]:
```

	Open	High	Low	Close	Volume	Adj Close
Date						
2014-09-16	99.80	101.26	98.89	100.86	66818200	100.86
2014-09-15	102.81	103.05	101.44	101.63	61216500	101.63
2014-09-12	101.21	102.19	101.08	101.66	62626100	101.66
2014-09-11	100.41	101.44	99.62	101.43	62353100	101.43
2014-09-10	98.01	101.11	97.76	101.00	100741900	101.00

```
In [11]: AAPL.head(2)
```

```
Out[11]:
```

	Open	High	Low	Close	Volume	Adj Close
Date						
2014-09-16	99.80	101.26	98.89	100.86	66818200	100.86
2014-09-15	102.81	103.05	101.44	101.63	61216500	101.63



tail()

```
In [12]: AAPL.tail()
```

```
Out[12]:
```

	Open	High	Low	Close	Volume	Adj Close
Date						
1980-12-18	26.63	26.75	26.63	26.63	18362400	0.41
1980-12-17	25.87	26.00	25.87	25.87	21610400	0.40
1980-12-16	25.37	25.37	25.25	25.25	26432000	0.39
1980-12-15	27.38	27.38	27.25	27.25	43971200	0.42
1980-12-12	28.75	28.87	28.75	28.75	117258400	0.45

```
In [13]: AAPL.tail(3)
```

```
Out[13]:
```

	Open	High	Low	Close	Volume	Adj Close
Date						
1980-12-16	25.37	25.37	25.25	25.25	26432000	0.39
1980-12-15	27.38	27.38	27.25	27.25	43971200	0.42
1980-12-12	28.75	28.87	28.75	28.75	117258400	0.45



info()

```
In [14]: AAPL.info()
Out[14]:
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 8514 entries, 2014-09-16 to 1980-12-12
Data columns (total 6 columns):
Open           8514 non-null float64
High           8514 non-null float64
Low            8514 non-null float64
Close          8514 non-null float64
Volume         8514 non-null int64
Adj Close      8514 non-null float64
dtypes: float64(5), int64(1)
memory usage: 465.6 KB
```



Broadcasting

```
In [15]: import numpy as np
```

```
In [16]: AAPL.iloc[:, 3, -1] = np.nan
```

← Assigning scalar value to column slice *broadcasts* value to each row.

```
In [17]: AAPL.head(6)
```

```
Out[17]:
```

	Open	High	Low	Close	Volume	Adj Close
Date						
2014-09-16	99.80	101.26	98.89	100.86	66818200	NaN
2014-09-15	102.81	103.05	101.44	101.63	61216500	101.63
2014-09-12	101.21	102.19	101.08	101.66	62626100	101.66
2014-09-11	100.41	101.44	99.62	101.43	62353100	NaN
2014-09-10	98.01	101.11	97.76	101.00	100741900	101.00
2014-09-09	99.08	103.08	96.14	97.99	189560600	97.99
2014-09-08	99.30	99.31	98.05	98.36	46277800	NaN



Broadcasting

```
In [18]: AAPL.info()
Out[18]:
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 8514 entries, 2014-09-16 to 1980-12-12
Data columns (total 6 columns):
Open                8514 non-null float64
High                8514 non-null float64
Low                 8514 non-null float64
Close               8514 non-null float64
Volume              8514 non-null int64
Adj Close           5676 non-null float64
dtypes: float64(5), int64(1)
memory usage: 465.6 KB
```



Series

```
In [19]: low = AAPL['Low']
```

```
In [20]: type(low)
```

```
Out[20]: pandas.core.series.Series
```

```
In [21]: low.head()
```

```
Out[21]:
```

Date

2014-09-16	98.89
------------	-------

2014-09-15	101.44
------------	--------

2014-09-12	101.08
------------	--------

2014-09-11	99.62
------------	-------

2014-09-10	97.76
------------	-------

Name: Low, dtype: float64

```
In [22]: lows = low.values
```

```
In [23]: type(lows)
```

```
Out[23]: numpy.ndarray
```



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Let's practice!



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Building DataFrames from scratch



DataFrames from CSV files

```
In [1]: import pandas as pd
```

```
In [2]: users = pd.read_csv('datasets/users.csv', index_col=0)
```

```
In [3]: print(users)
```

```
Out[3]:
```

	weekday	city	visitors	signups
0	Sun	Austin	139	7
1	Sun	Dallas	237	12
2	Mon	Austin	326	3
3	Mon	Dallas	456	5



DataFrames from dict (1)

```
In [1]: import pandas as pd
```

```
In [2]: data = {'weekday': ['Sun', 'Sun', 'Mon', 'Mon'],  
...:           'city': ['Austin', 'Dallas', 'Austin', 'Dallas'],  
...:           'visitors': [139, 237, 326, 456],  
...:           'signups': [7, 12, 3, 5]}
```

```
In [3]: users = pd.DataFrame(data)
```

```
In [4]: print(users)
```

```
Out[4]:
```

	weekday	city	visitors	signups
0	Sun	Austin	139	7
1	Sun	Dallas	237	12
2	Mon	Austin	326	3
3	Mon	Dallas	456	5



DataFrames from dict (2)

```
In [1]: import pandas as pd
```

```
In [2]: cities = ['Austin', 'Dallas', 'Austin', 'Dallas']
```

```
In [3]: signups = [7, 12, 3, 5]
```

```
In [4]: visitors = [139, 237, 326, 456]
```

```
In [5]: weekdays = ['Sun', 'Sun', 'Mon', 'Mon']
```

```
In [6]: list_labels = ['city', 'signups', 'visitors', 'weekday']
```

```
In [7]: list_cols = [cities, signups, visitors, weekdays]
```

```
In [8]: zipped = list(zip(list_labels, list_cols))
```



DataFrames from dict (3)

```
In [9]: print(zipped)
```

```
Out[9]:
```

```
[('city', ['Austin', 'Dallas', 'Austin', 'Dallas']), ('signups',  
[7, 12, 3, 5]), ('visitors', [139, 237, 326, 456]), ('weekday',  
['Sun', 'Sun', 'Mon', 'Mon'])]
```

```
In [10]: data = dict(zipped)
```

```
In [11]: users = pd.DataFrame(data)
```

```
In [12]: print(users)
```

```
Out[12]:
```

	weekday	city	visitors	signups
0	Sun	Austin	139	7
1	Sun	Dallas	237	12
2	Mon	Austin	326	3
3	Mon	Dallas	456	5



Broadcasting

```
In [13]: users['fees'] = 0 # Broadcasts to entire column
```

```
In [14]: print(users)
```

```
Out[14]:
```

	city	signups	visitors	weekday	fees
0	Austin	7	139	Sun	0
1	Dallas	12	237	Sun	0
2	Austin	3	326	Mon	0
3	Dallas	5	456	Mon	0



Broadcasting with a dict

```
In [1]: import pandas as pd
```

```
In [2]: heights = [ 59.0, 65.2, 62.9, 65.4, 63.7, 65.7, 64.1 ]
```

```
In [3]: data = {'height': heights, 'sex': 'M'}
```

```
In [4]: results = pd.DataFrame(data)
```

```
In [5]: print(results)
```

```
Out[5]:
```

	height	sex
0	59.0	M
1	65.2	M
2	62.9	M
3	65.4	M
4	63.7	M
5	65.7	M
6	64.1	M



Index and columns

```
In [6]: results.columns = ['height (in)', 'sex']
```

```
In [7]: results.index = ['A', 'B', 'C', 'D', 'E', 'F', 'G']
```

```
In [8]: print(results)
```

```
Out[8]:
```

	height (in)	sex
A	59.0	M
B	65.2	M
C	62.9	M
D	65.4	M
E	63.7	M
F	65.7	M
G	64.1	M



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Let's practice!



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Importing & exporting data



Original CSV file

- Dataset: Sunspot observations collected from SILSO

```
1818,01,01,1818.004, -1,1
1818,01,02,1818.007, -1,1
1818,01,03,1818.010, -1,1
1818,01,04,1818.012, -1,1
1818,01,05,1818.015, -1,1
1818,01,06,1818.018, -1,1
...
```



Datasets from CSV files

```
In [1]: import pandas as pd
```

```
In [2]: filepath = 'ISSN_D_tot.csv'
```

```
In [3]: sunspots = pd.read_csv(filepath)
```

```
In [4]: sunspots.info()
```

```
<class 'pandas.core.frame.DataFrame'>
```

```
RangeIndex: 71921 entries, 0 to 71920
```

```
Data columns (total 6 columns):
```

1818	71921 non-null	int64
01	71921 non-null	int64
01.1	71921 non-null	int64
1818.004	71921 non-null	float64
-1	71921 non-null	int64
1	71921 non-null	int64

```
dtypes: float64(1), int64(5)
```

```
memory usage: 3.3 MB
```



Datasets from CSV files

```
In [5]: sunspots.iloc[10:20, :]
```

```
Out[5]:
```

	1818	01	01.1	1818.004	-1	1
10	1818	1	12	1818.034	-1	1
11	1818	1	13	1818.037	22	1
12	1818	1	14	1818.040	-1	1
13	1818	1	15	1818.042	-1	1
14	1818	1	16	1818.045	-1	1
15	1818	1	17	1818.048	46	1
16	1818	1	18	1818.051	59	1
17	1818	1	19	1818.053	63	1
18	1818	1	20	1818.056	-1	1
19	1818	1	21	1818.059	-1	1

Problems

- CSV file has no column headers
 - Columns 0-2: Gregorian date (year, month, day)
 - Column 3: Date as fraction as year
 - Column 4: Daily total sunspot number
 - Column 5: Definitive/provisional indicator (1 or 0)
- Missing values in column 4: indicated by -1
- Dates representation inconvenient



Using header keyword

```
In [6]: sunspots = pd.read_csv(filepath, header=None)
```

```
In [7]: sunspots.iloc[10:20, :]
```

```
Out[7]:
```

	0	1	2	3	4	5
10	1818	1	11	1818.031	-1	1
11	1818	1	12	1818.034	-1	1
12	1818	1	13	1818.037	22	1
13	1818	1	14	1818.040	-1	1
14	1818	1	15	1818.042	-1	1
15	1818	1	16	1818.045	-1	1
16	1818	1	17	1818.048	46	1
17	1818	1	18	1818.051	59	1
18	1818	1	19	1818.053	63	1
19	1818	1	20	1818.056	-1	1



Using names keyword

```
In [8]: col_names = ['year', 'month', 'day', 'dec_date',  
....:                  'sunspots', 'definite']
```

```
In [9]: sunspots = pd.read_csv(filepath, header=None,  
....:                          names=col_names)
```

```
In [10]: sunspots.iloc[10:20, :]
```

```
Out[10]:
```

	year	month	day	dec_date	sunspots	definite
10	1818	1	11	1818.031	-1	1
11	1818	1	12	1818.034	-1	1
12	1818	1	13	1818.037	22	1
13	1818	1	14	1818.040	-1	1
14	1818	1	15	1818.042	-1	1
15	1818	1	16	1818.045	-1	1
16	1818	1	17	1818.048	46	1
17	1818	1	18	1818.051	59	1
18	1818	1	19	1818.053	63	1
19	1818	1	20	1818.056	-1	1



Using na_values keyword (1)

```
In [11]: sunspots = pd.read_csv(filepath, header=None,  
    ....:                        names=col_names, na_values='-1')
```

```
In [12]: sunspots.iloc[10:20, :]
```

```
Out[12]:
```

	year	month	day	dec_date	sunspots	definite
10	1818	1	11	1818.031	-1	1
11	1818	1	12	1818.034	-1	1
12	1818	1	13	1818.037	22	1
13	1818	1	14	1818.040	-1	1
14	1818	1	15	1818.042	-1	1
15	1818	1	16	1818.045	-1	1
16	1818	1	17	1818.048	46	1
17	1818	1	18	1818.051	59	1
18	1818	1	19	1818.053	63	1
19	1818	1	20	1818.056	-1	1



Using na_values keyword (2)

```
In [13]: sunspots = pd.read_csv(filepath, header=None,  
    ....:                        names=col_names, na_values=' -1')
```

```
In [14]: sunspots.iloc[10:20, :]
```

```
Out[14]:
```

	year	month	day	dec_date	sunspots	definite
10	1818	1	11	1818.031	NaN	1
11	1818	1	12	1818.034	NaN	1
12	1818	1	13	1818.037	22.0	1
13	1818	1	14	1818.040	NaN	1
14	1818	1	15	1818.042	NaN	1
15	1818	1	16	1818.045	NaN	1
16	1818	1	17	1818.048	46.0	1
17	1818	1	18	1818.051	59.0	1
18	1818	1	19	1818.053	63.0	1
19	1818	1	20	1818.056	NaN	1



Using na_values keyword (3)

```
In [15]: sunspots = pd.read_csv(filepath, header=None,  
    ...: names=col_names, na_values={'sunspots': ['-1']})
```

```
In [16]: sunspots.iloc[10:20, :]
```

```
Out[16]:
```

	year	month	day	dec_date	sunspots	definite
10	1818	1	11	1818.031	NaN	1
11	1818	1	12	1818.034	NaN	1
12	1818	1	13	1818.037	22.0	1
13	1818	1	14	1818.040	NaN	1
14	1818	1	15	1818.042	NaN	1
15	1818	1	16	1818.045	NaN	1
16	1818	1	17	1818.048	46.0	1
17	1818	1	18	1818.051	59.0	1
18	1818	1	19	1818.053	63.0	1
19	1818	1	20	1818.056	NaN	1



Using parse_dates keyword

```
In [17]: sunspots = pd.read_csv(filepath, header=None,  
...: names=col_names, na_values={'sunspots': ['-1']},  
...: parse_dates=[[0, 1, 2]])
```

```
In [18]: sunspots.iloc[10:20, :]
```

```
Out[18]:
```

	year_month_day	dec_date	sunspots	definite
10	1818-01-11	1818.031	NaN	1
11	1818-01-12	1818.034	NaN	1
12	1818-01-13	1818.037	22.0	1
13	1818-01-14	1818.040	NaN	1
14	1818-01-15	1818.042	NaN	1
15	1818-01-16	1818.045	NaN	1
16	1818-01-17	1818.048	46.0	1
17	1818-01-18	1818.051	59.0	1
18	1818-01-19	1818.053	63.0	1
19	1818-01-20	1818.056	NaN	1



Inspecting DataFrame

```
In [19]: sunspots.info()
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 71922 entries, 0 to 71921
Data columns (total 4 columns):
year_month_day      71922 non-null datetime64[ns]
dec_date            71922 non-null float64
sunspots            68675 non-null float64
definite            71922 non-null int64
dtypes: datetime64[ns](1), float64(2), int64(1)
memory usage: 2.2 MB
```



Using dates as index

```
In [20]: sunspots.index = sunspots['year_month_day']
```

```
In [21]: sunspots.index.name = 'date'
```

```
In [22]: sunspots.info()
```

```
Out[22]:
```

```
<class 'pandas.core.frame.DataFrame'>
```

```
DatetimeIndex: 71922 entries, 1818-01-01 to 2014-11-30
```

```
Data columns (total 4 columns):
```

```
year_month_day    71922 non-null datetime64[ns]
```

```
dec_date          71922 non-null float64
```

```
sunspots          68675 non-null float64
```

```
definite          71922 non-null int64
```

```
dtypes: datetime64[ns](1), float64(2), int64(1)
```

```
memory usage: 2.7 MB
```



Trimming redundant columns

```
In [23]: cols = ['sunspots', 'definite']
```

```
In [24]: sunspots = sunspots[cols]
```

```
In [25]: sunspots.iloc[10:20, :]
```

```
Out[25]:
```

	sunspots	definite
date		
1818-01-11	NaN	1
1818-01-12	NaN	1
1818-01-13	22.0	1
1818-01-14	NaN	1
1818-01-15	NaN	1
1818-01-16	NaN	1
1818-01-17	46.0	1
1818-01-18	59.0	1
1818-01-19	63.0	1
1818-01-20	NaN	1



Writing files

```
In [26]: out_csv = 'sunspots.csv'
```

```
In [27]: sunspots.to_csv(out_csv)
```

```
In [28]: out_tsv = 'sunspots.tsv'
```

```
In [29]: sunspots.to_csv(out_tsv, sep='\t')
```

```
In [30]: out_xlsx = 'sunspots.xlsx'
```

```
In [31]: sunspots.to_excel(out_xlsx)
```



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Plotting with pandas



AAPL stock data

```
In [1]: import pandas as pd
```

```
In [2]: import matplotlib.pyplot as plt
```

```
In [3]: aapl = pd.read_csv('aapl.csv', index_col='date',  
....:                      parse_dates=True)
```

```
In [4]: aapl.head(6)
```

```
Out[4]:
```

	adj_close	close	high	low	open	volume
date						
2000-03-01	31.68	130.31	132.06	118.50	118.56	38478000
2000-03-02	29.66	122.00	127.94	120.69	127.00	11136800
2000-03-03	31.12	128.00	128.23	120.00	124.87	11565200
2000-03-06	30.56	125.69	129.13	125.00	126.00	7520000
2000-03-07	29.87	122.87	127.44	121.12	126.44	9767600
2000-03-08	29.66	122.00	123.94	118.56	122.87	9690800



Plotting arrays (matplotlib)

```
In [5]: close_arr = aapl['close'].values
```

```
In [6]: type(close_arr)
```

```
Out[6]: numpy.ndarray
```

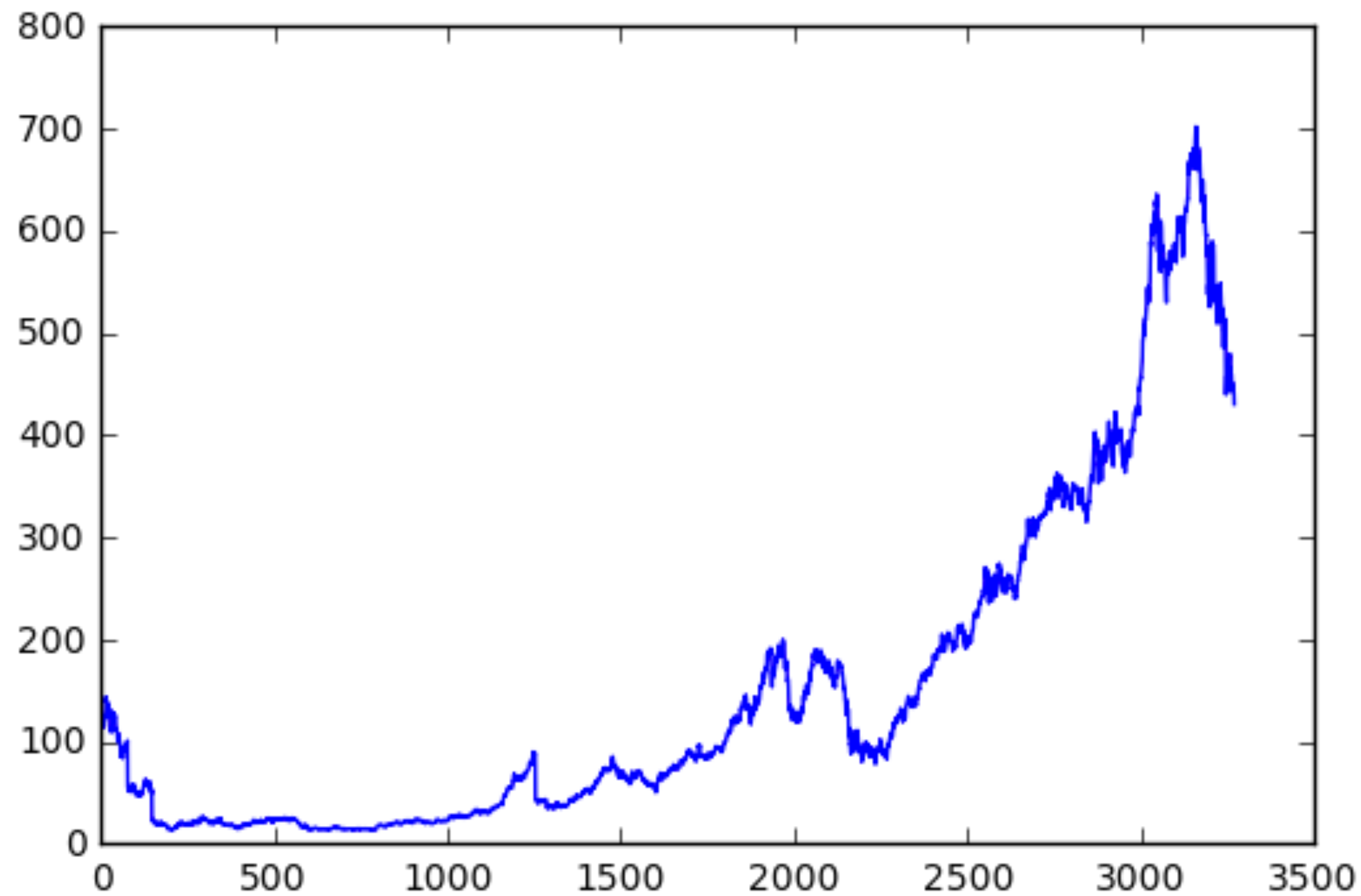
```
In [7]: plt.plot(close_arr)
```

```
Out[7]: [<matplotlib.lines.Line2D at 0x115550358>]
```

```
In [8]: plt.show()
```



Plotting arrays (Matplotlib)





Plotting Series (matplotlib)

```
In [9]: close_series = aapl['close']
```

```
In [10]: type(close_series)
```

```
Out[10]: pandas.core.series.Series
```

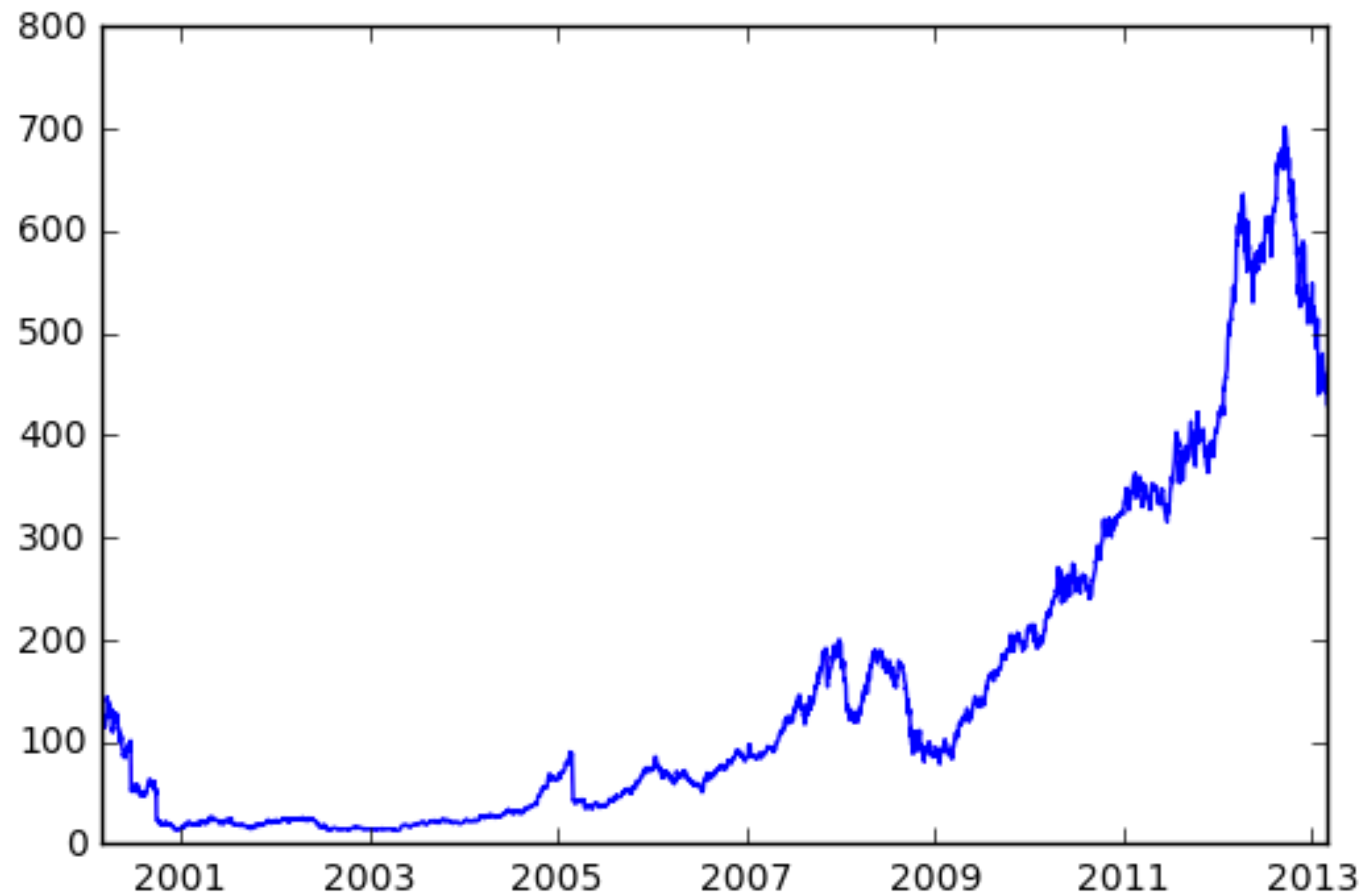
```
In [11]: plt.plot(close_series)
```

```
Out[11]: [<matplotlib.lines.Line2D at 0x11801cd30>]
```

```
In [12]: plt.show()
```



Plotting Series (matplotlib)



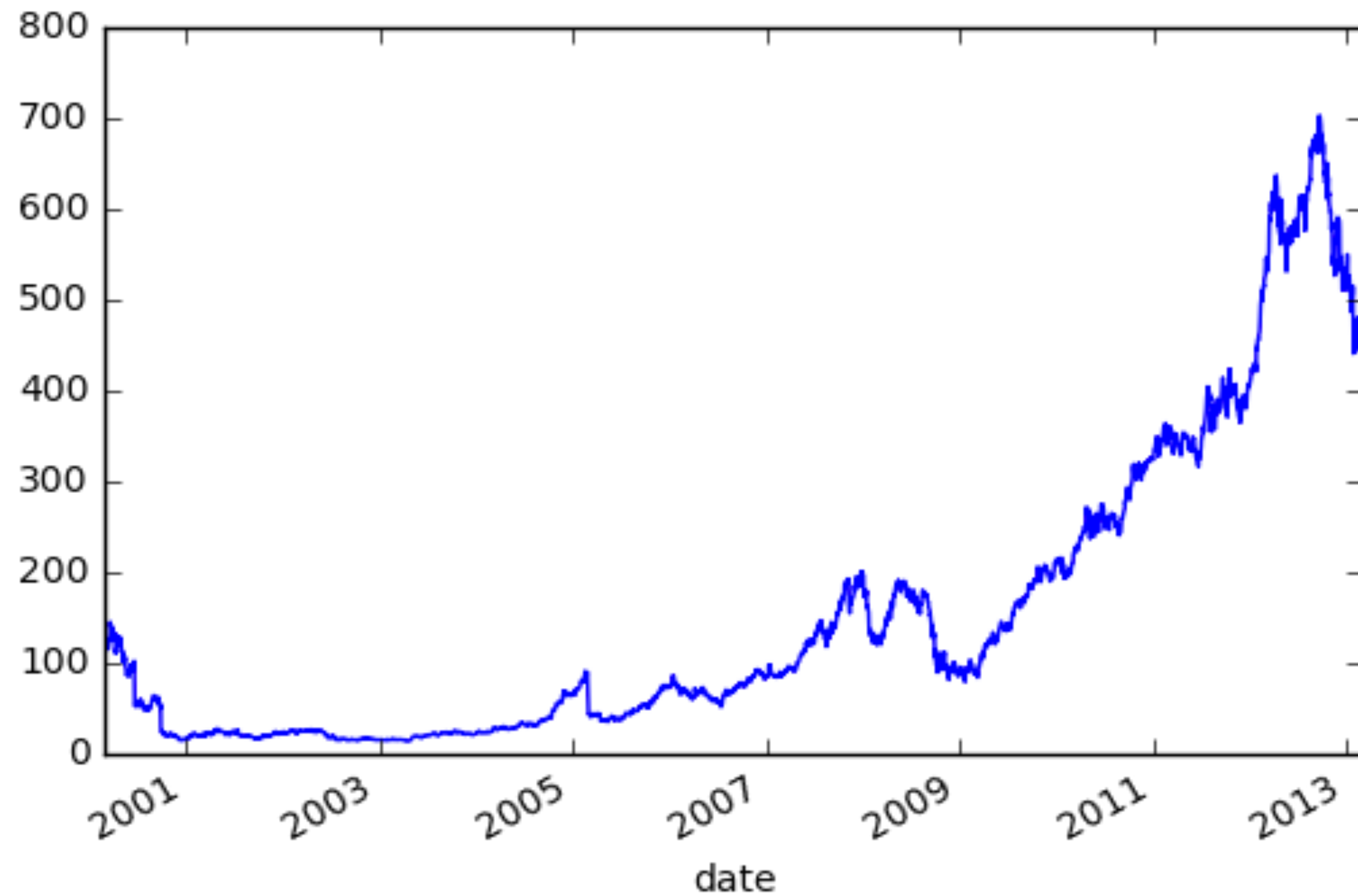
Plotting Series (pandas)

```
In [13]: close_series.plot() # plots Series directly
```

```
In [14]: plt.show()
```



Plotting Series (pandas)

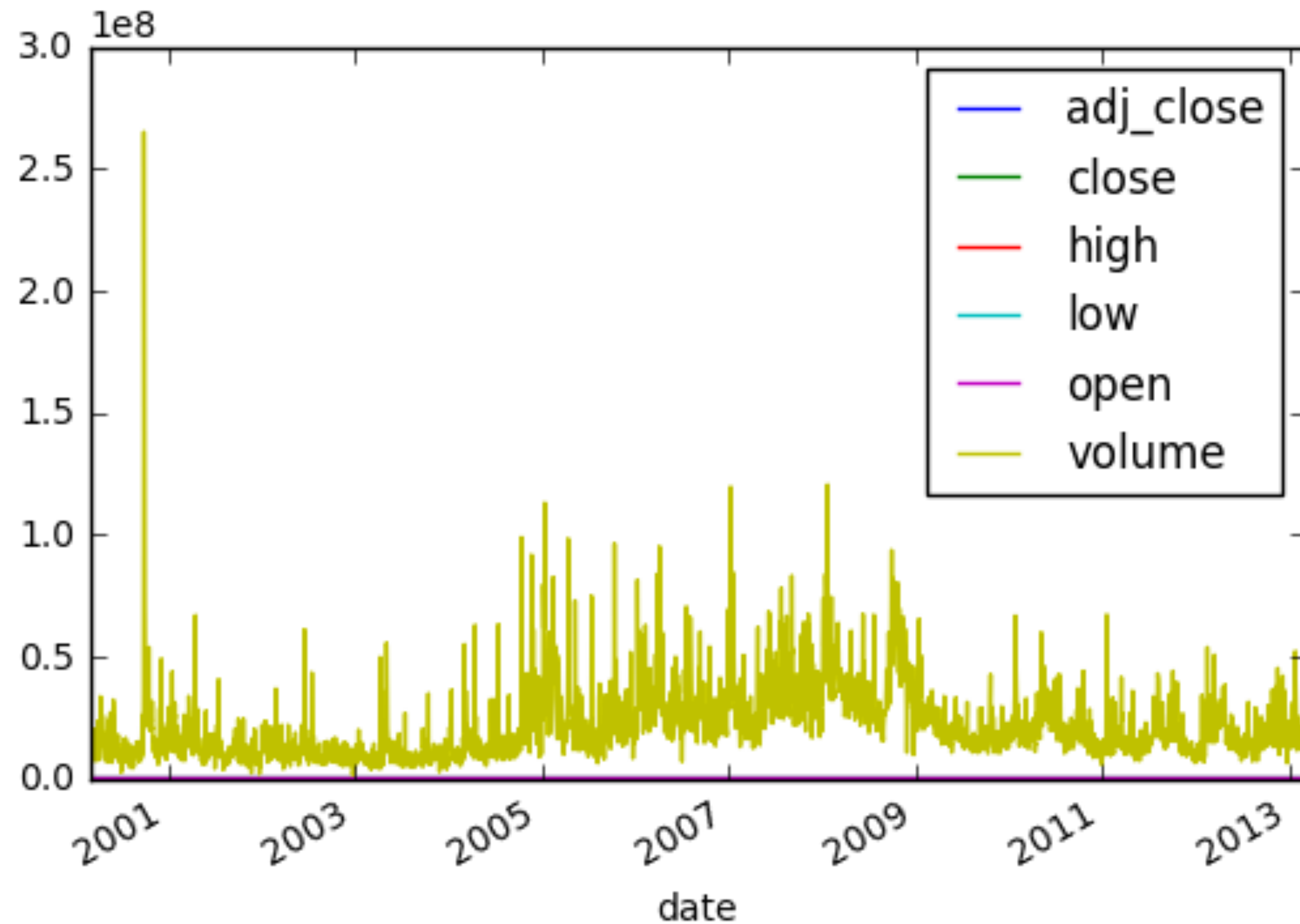


Plotting DataFrames (pandas)

```
In [15]: aapl.plot() # plots all Series at once  
Out[15]: <matplotlib.axes._subplots.AxesSubplot at 0x118039b38>  
  
In [16]: plt.show()
```



Plotting DataFrames (pandas)





Plotting DataFrames (matplotlib)

```
In [17]: plt.plot(aapl) # plots all columns at once
```

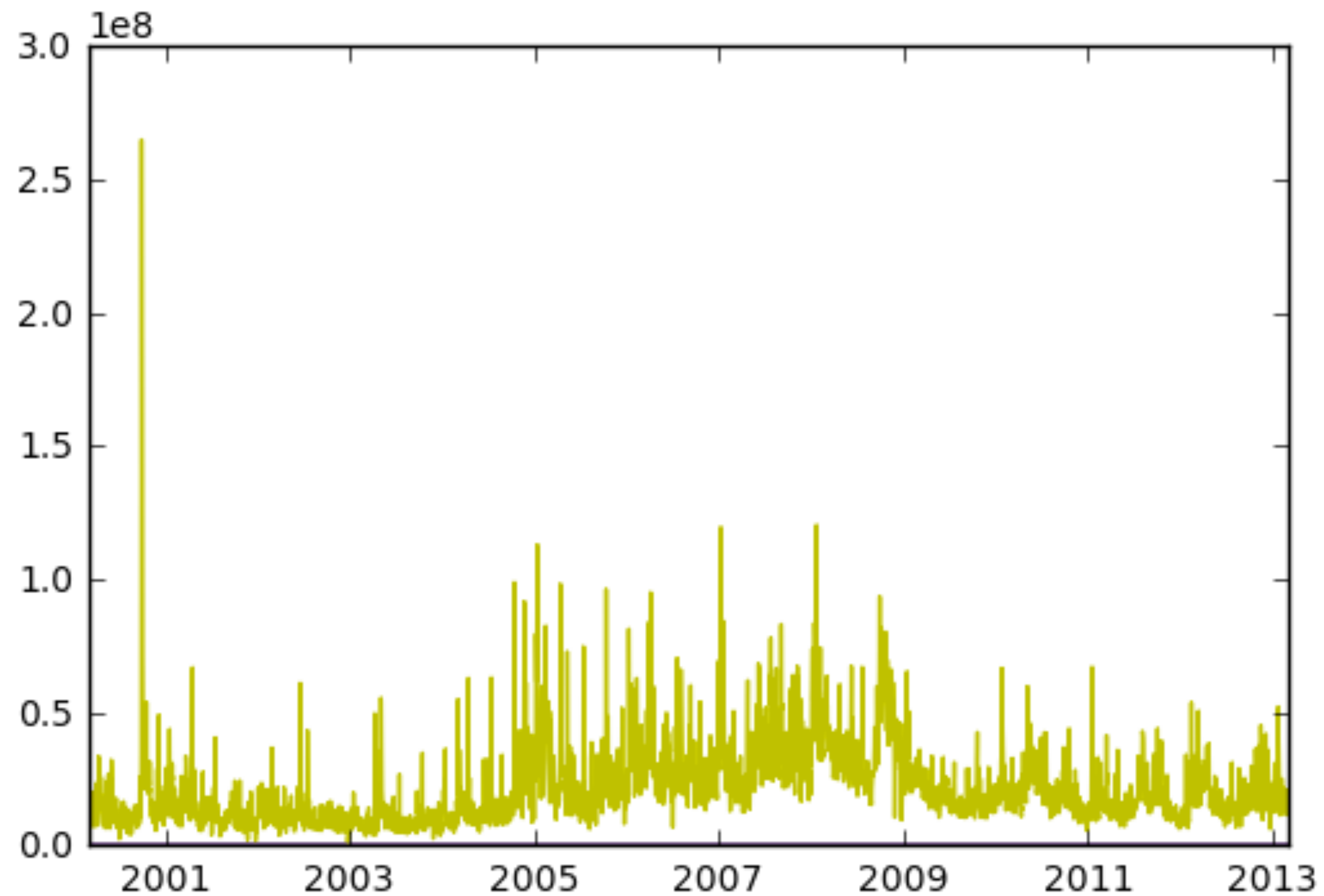
```
Out[17]:
```

```
<matplotlib.lines.Line2D at 0x1156290f0>,  
<matplotlib.lines.Line2D at 0x1156525f8>,  
<matplotlib.lines.Line2D at 0x1156527f0>,  
<matplotlib.lines.Line2D at 0x1156529e8>,  
<matplotlib.lines.Line2D at 0x115652be0>,  
<matplotlib.lines.Line2D at 0x115652dd8>
```

```
In [18]: plt.show()
```



Plotting DataFrames (matplotlib)





Fixing scales

```
In [19]: aapl.plot()
```

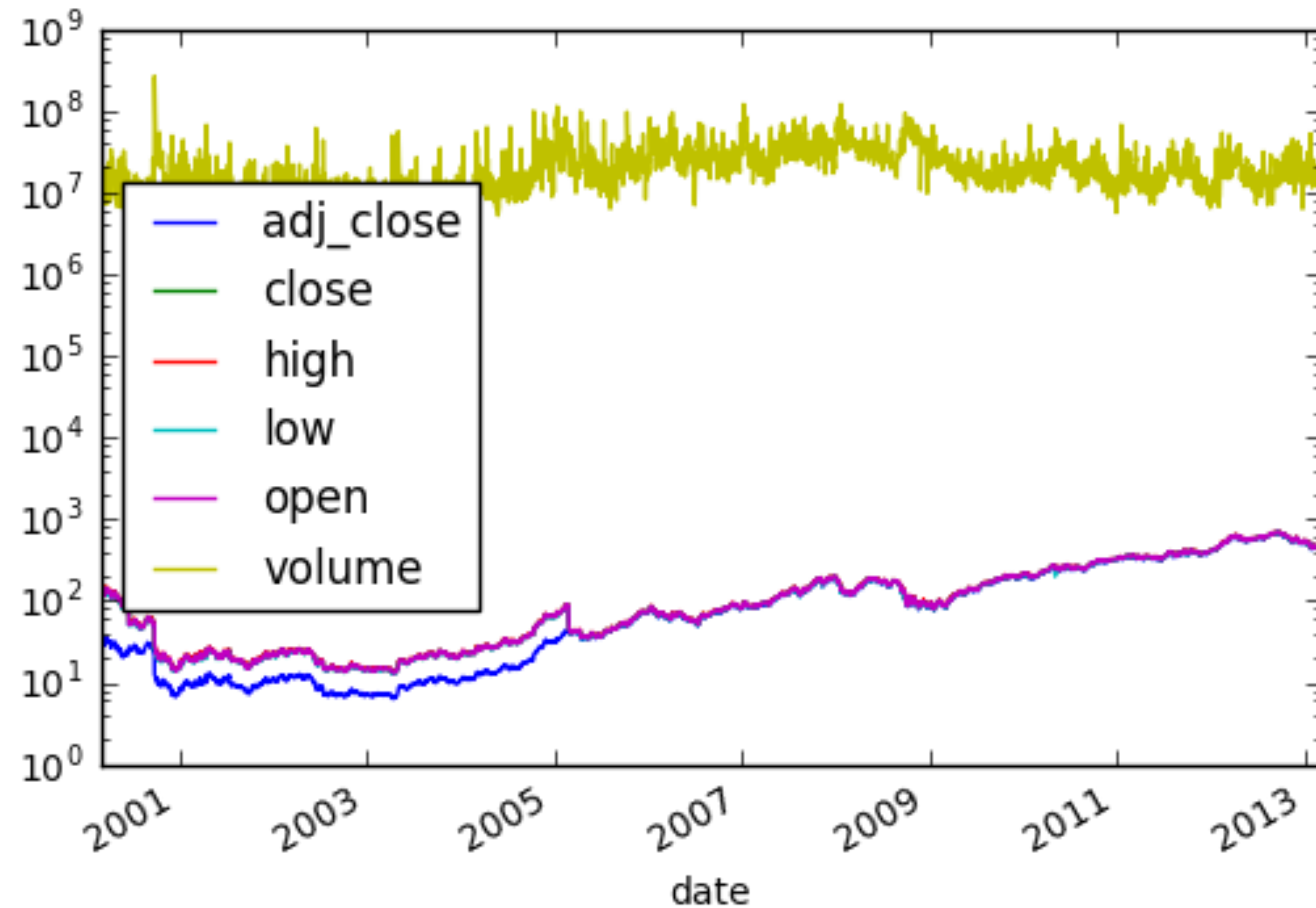
```
Out[19]: <matplotlib.axes._subplots.AxesSubplot at 0x118afe048>
```

```
In [20]: plt.yscale('log') # logarithmic scale on vertical axis
```

```
In [21]: plt.show()
```



Fixing scales





Customizing plots

```
In [22]: aapl['open'].plot(color='b', style='.-', legend=True)
Out[22]: <matplotlib.axes._subplots.AxesSubplot at 0x11a17db38>
```

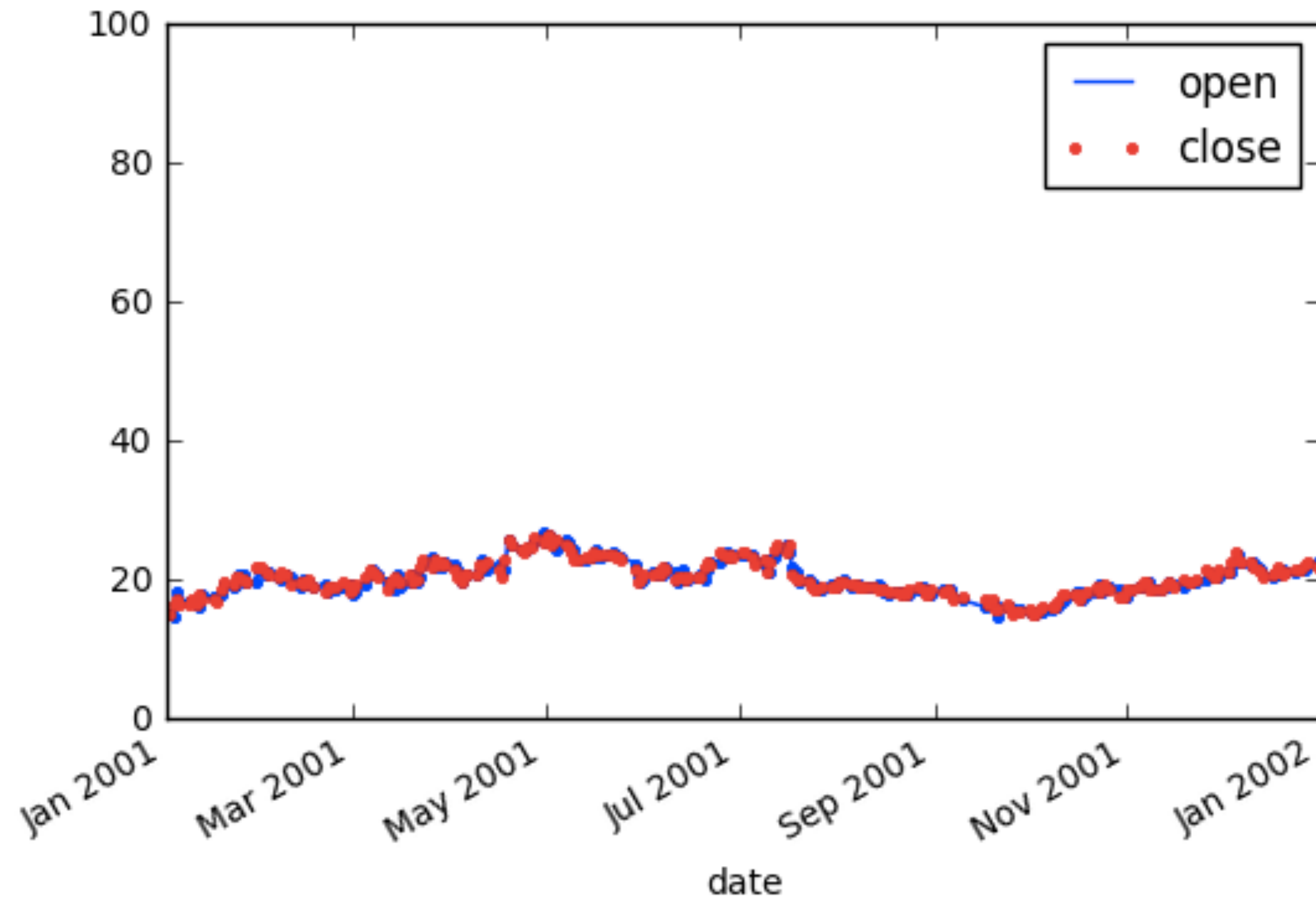
```
In [23]: aapl['close'].plot(color='r', style='.', legend=True)
Out[23]: <matplotlib.axes._subplots.AxesSubplot at 0x11a17db38>
```

```
In [24]: plt.axis(('2001', '2002', 0, 100))
Out[24]: ('2001', '2002', 0, 100)
```

```
In [25]: plt.show()
```

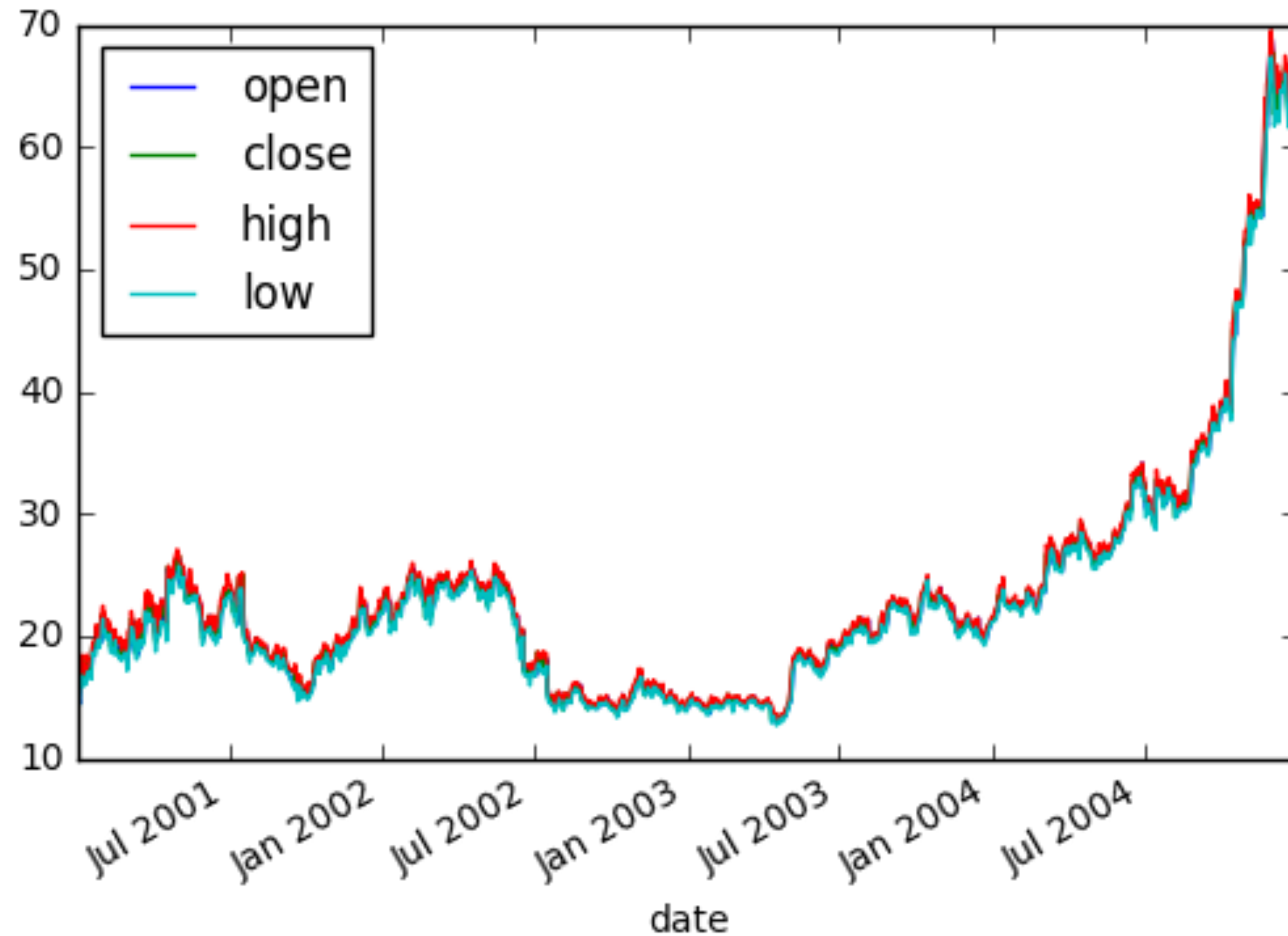


Customizing plots





Saving plots





Saving plots

```
In [26]: aapl.loc['2001':'2004',['open', 'close', 'high',  
....:      'low']].plot()  
Out[26]: <matplotlib.axes._subplots.AxesSubplot at 0x11ab42978>  
  
In [27]: plt.savefig('aapl.png')  
  
In [28]: plt.savefig('aapl.jpg')  
  
In [29]: plt.savefig('aapl.pdf')  
  
In [30]: plt.show()
```



PANDAS FOUNDATIONS

Let's practice!